Figure 7I: Predicted Noise Levels for Construction Phase (Site Preparation & Earthworks) – Within MAA Refinery Site

(Note: Background noise levels are not included. Site Preparation & Earthworks stage represents the worst case with respect to noise generation during the Construction Phase)

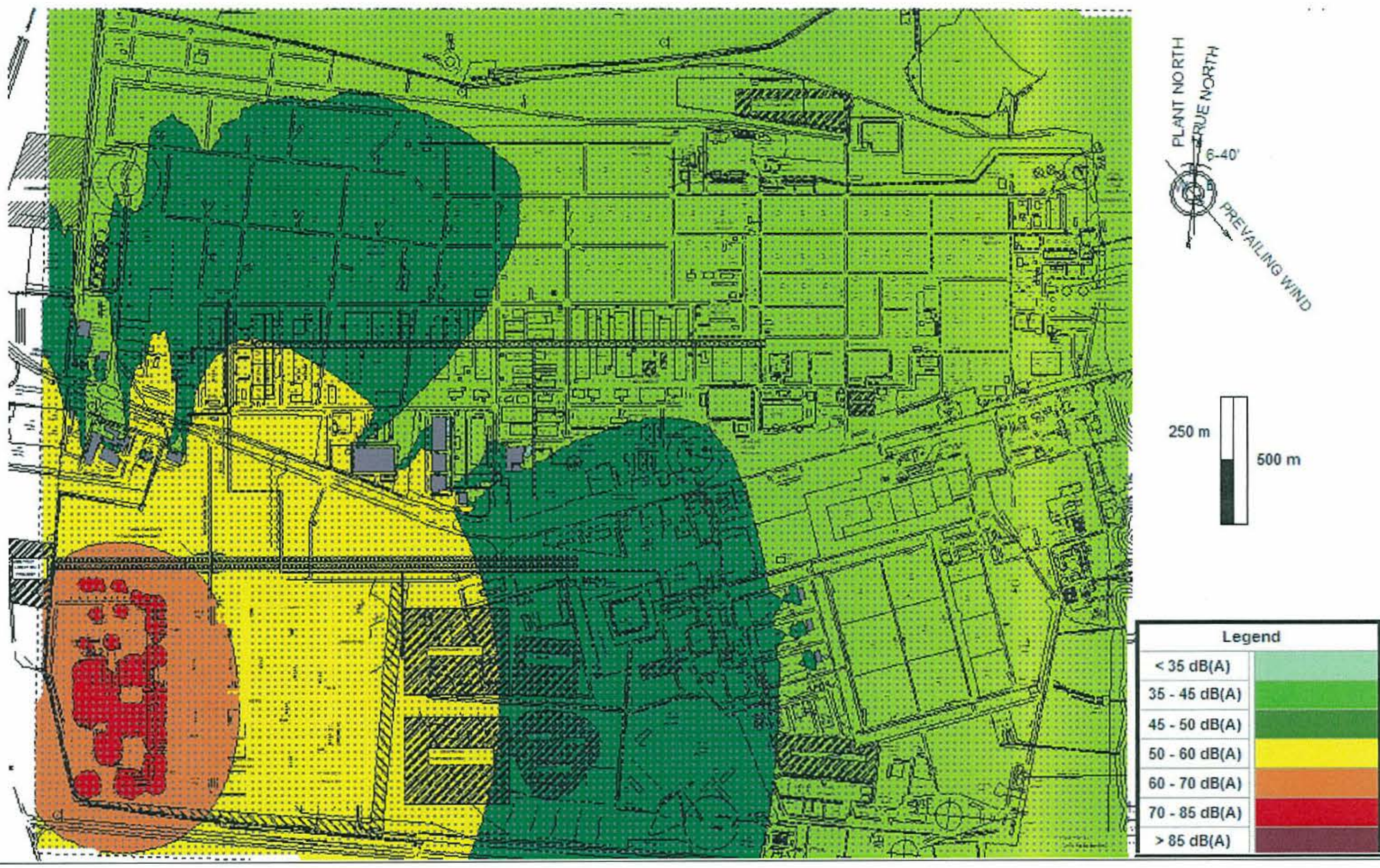

Figure 7J: Predicted Noise Levels for Construction Phase (Site Preparation & Earthworks) – Within MAA Area

(Note: Background noise levels are not included. Site Preparation & Earthworks stage represents the worst case with respect to noise generation during the Construction Phase)

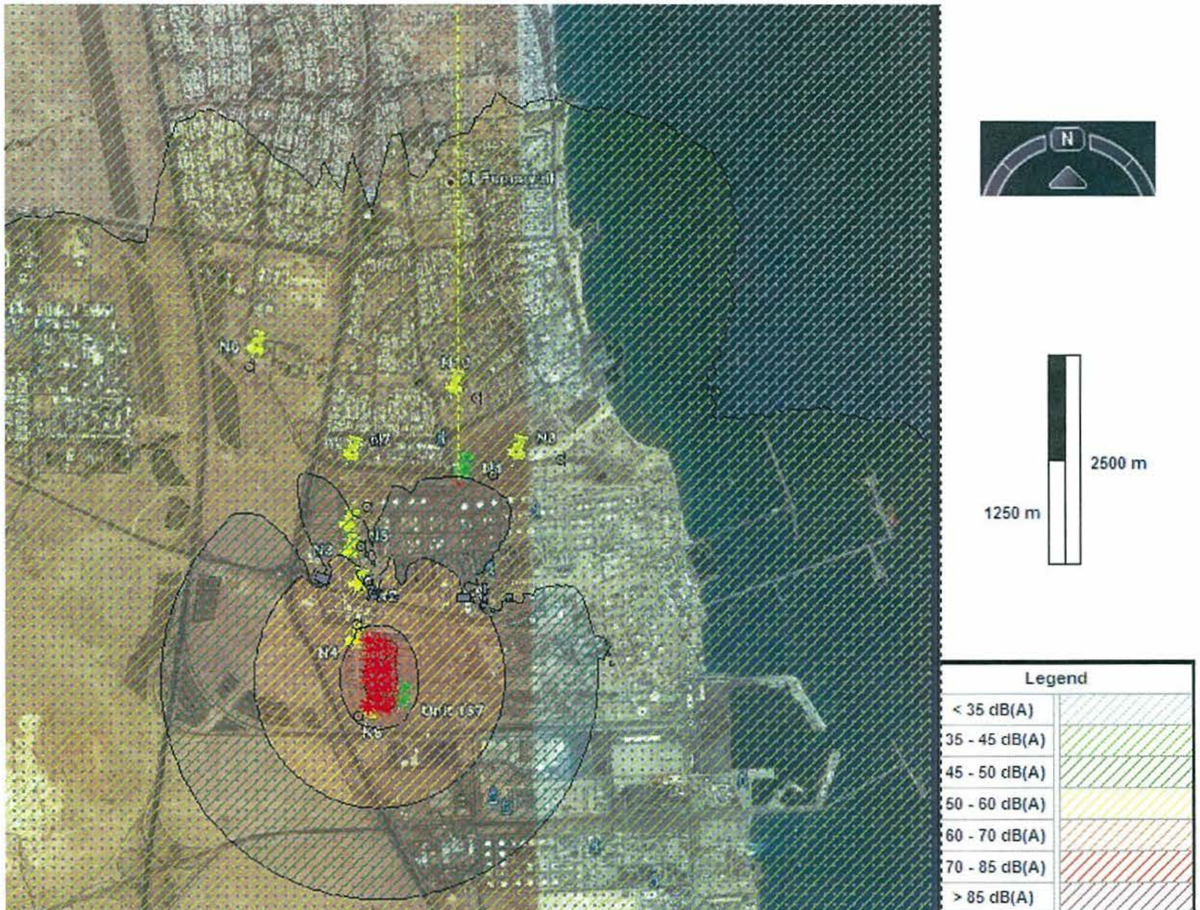

Figure 7K: Predicted Noise Levels for Operations Phase (Normal Plant Operation) - within MAA CFP Block

(Note: Background noise levels are not included. Under normal plant operation, flaring is at the minimal and flare noise is at the lowest.)

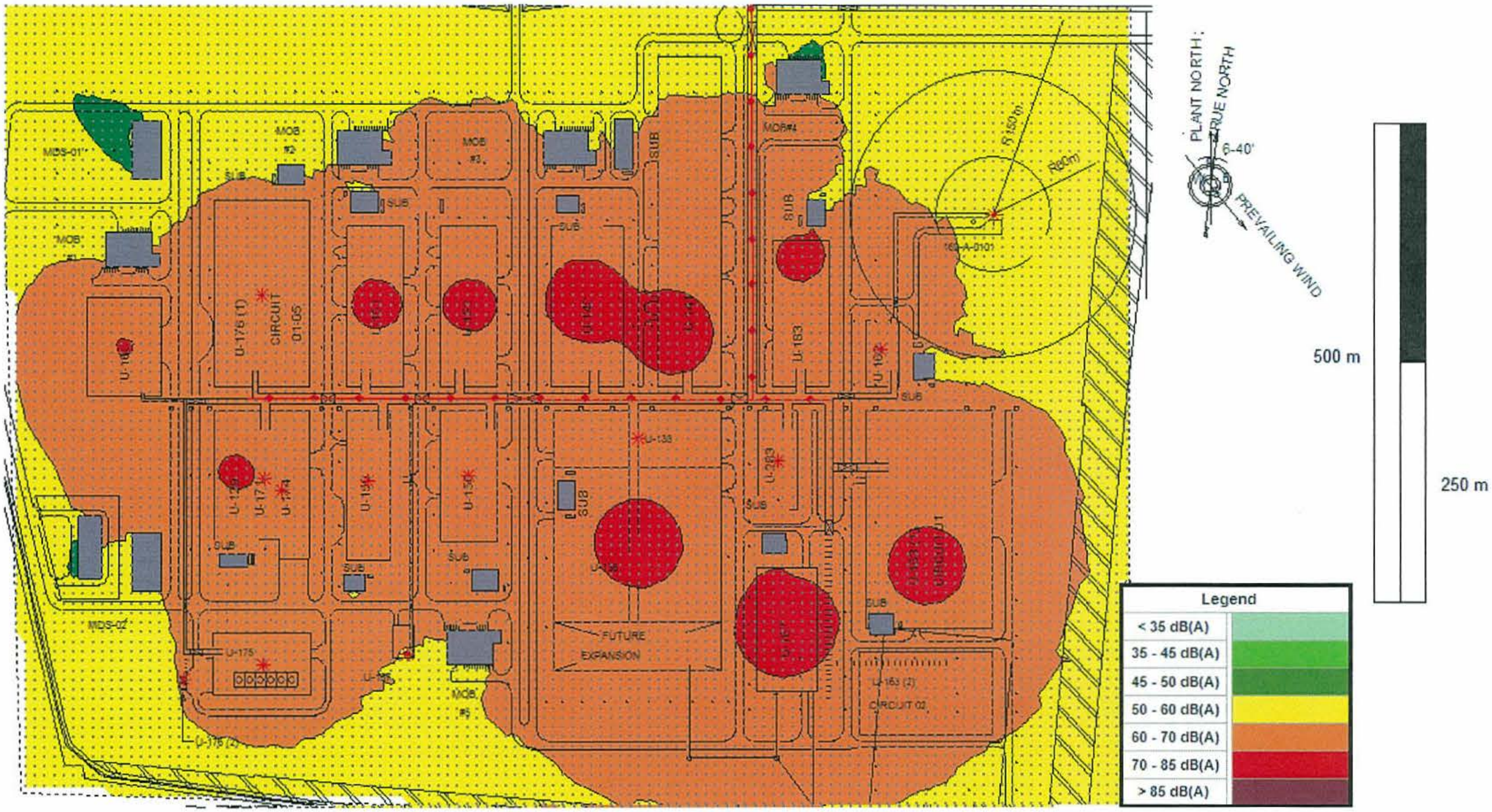

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Figure 7L: Predicted Noise Levels for Operations Phase (Normal Plant Operation) - within MAA Refinery Site

(Note: Background noise levels are not included. Under normal plant operation, flaring is at the minimal and flare noise is at the lowest.)

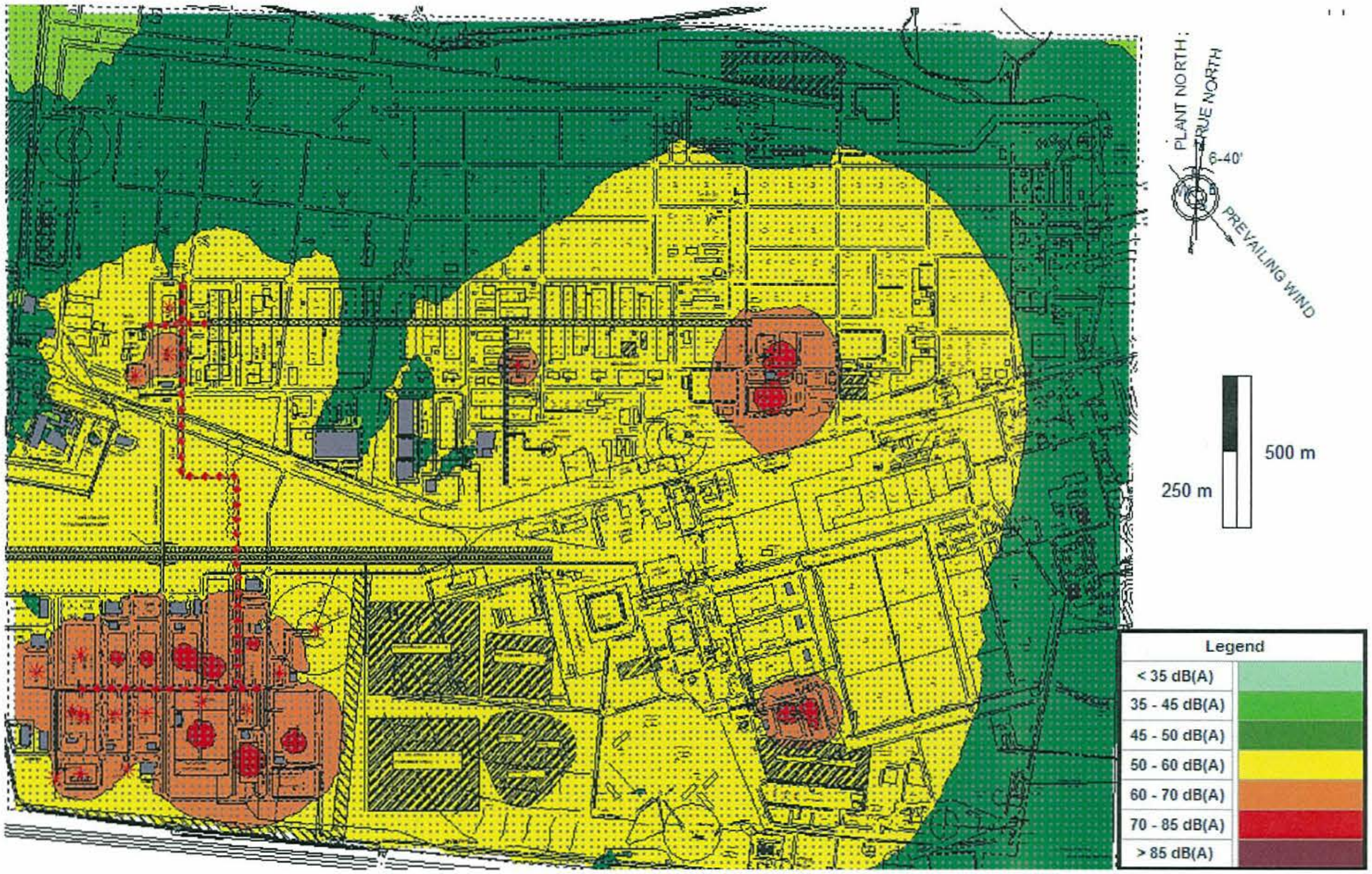


Figure 7M: Predicted Noise Levels for Operations Phase (Normal Plant Operation) - within MAA Area

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)

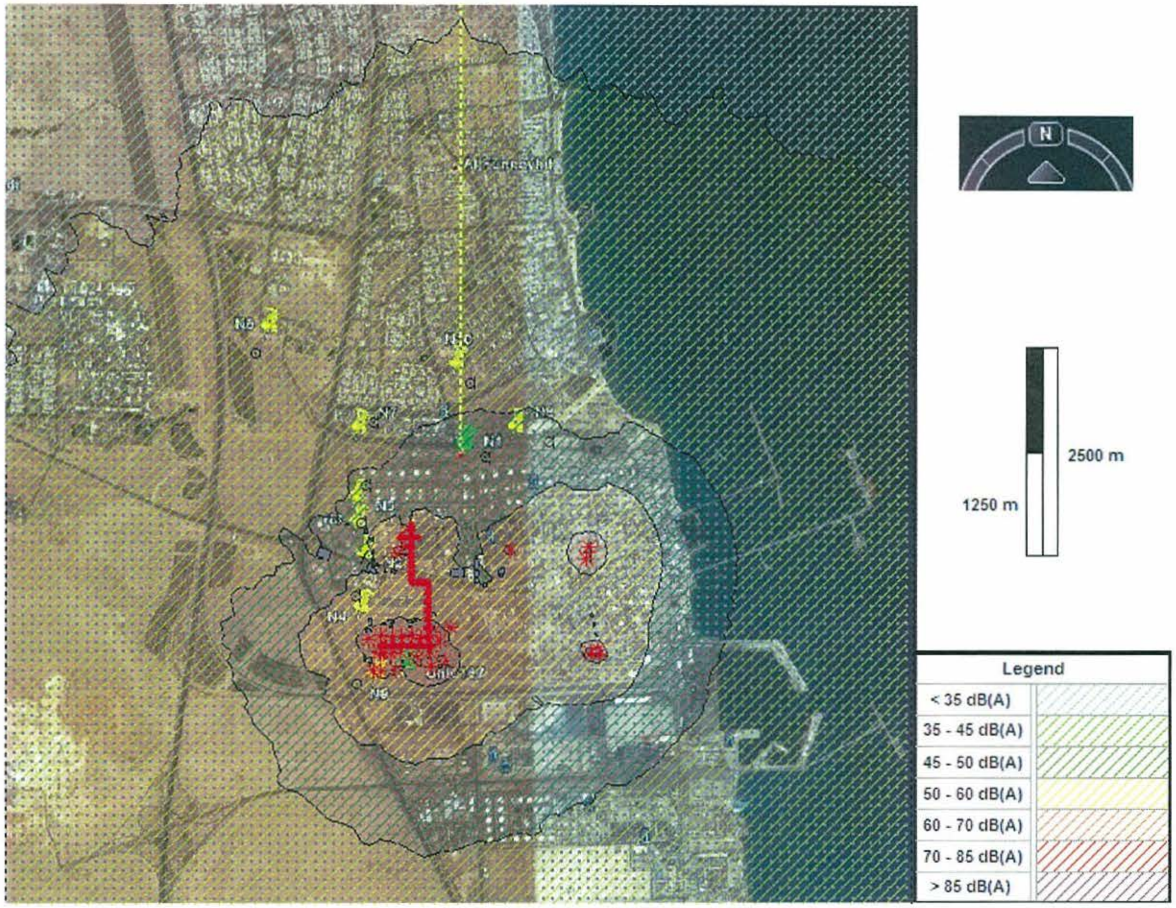


Figure 7N: Predicted Noise Levels for Operations Phase (Plant Upset Condition) – within MAA CFP Block

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)

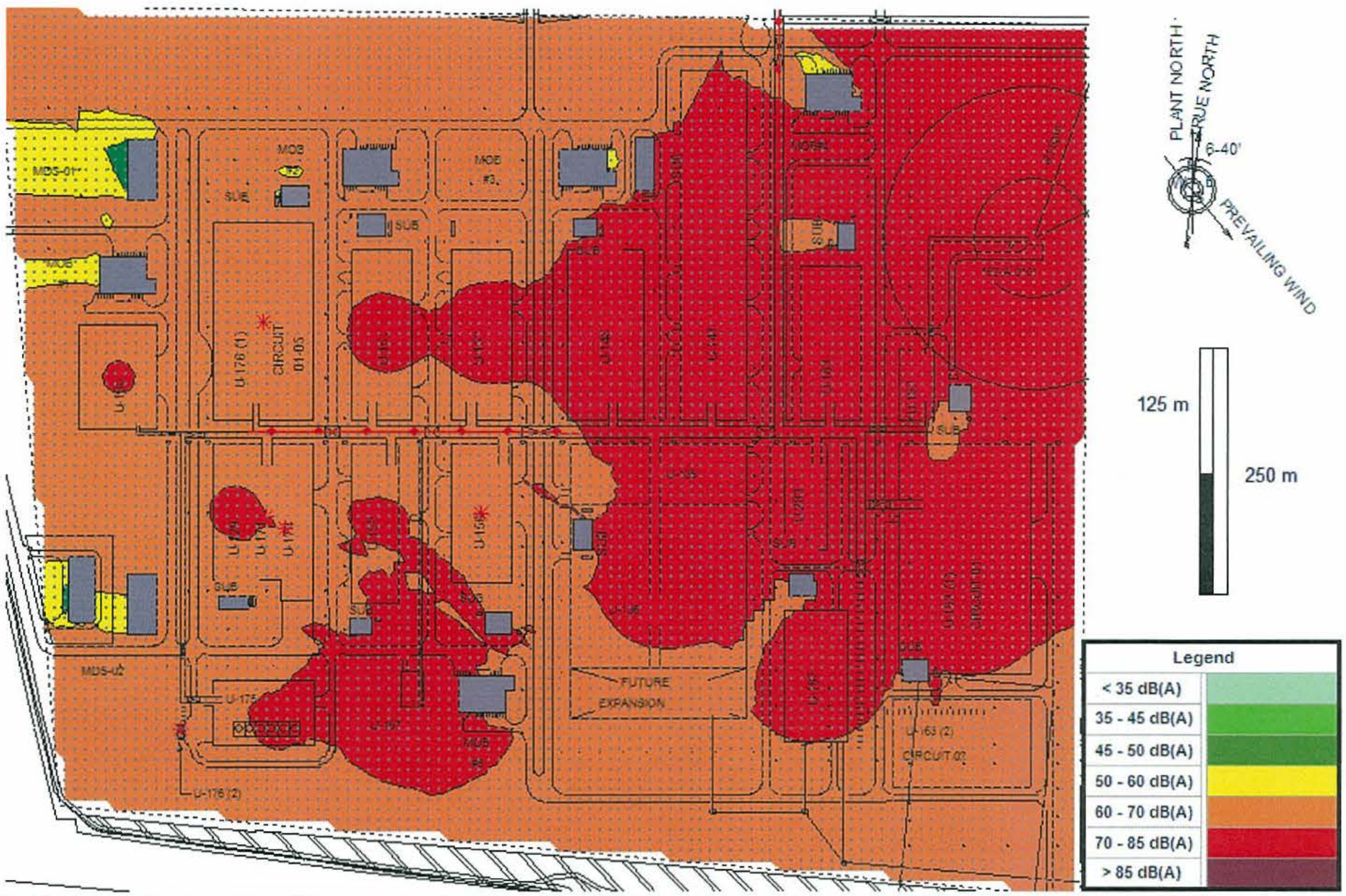


Figure 7O: Predicted Noise Levels for Operations Phase (Plant Upset Condition) – within MAA Refinery Site

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)

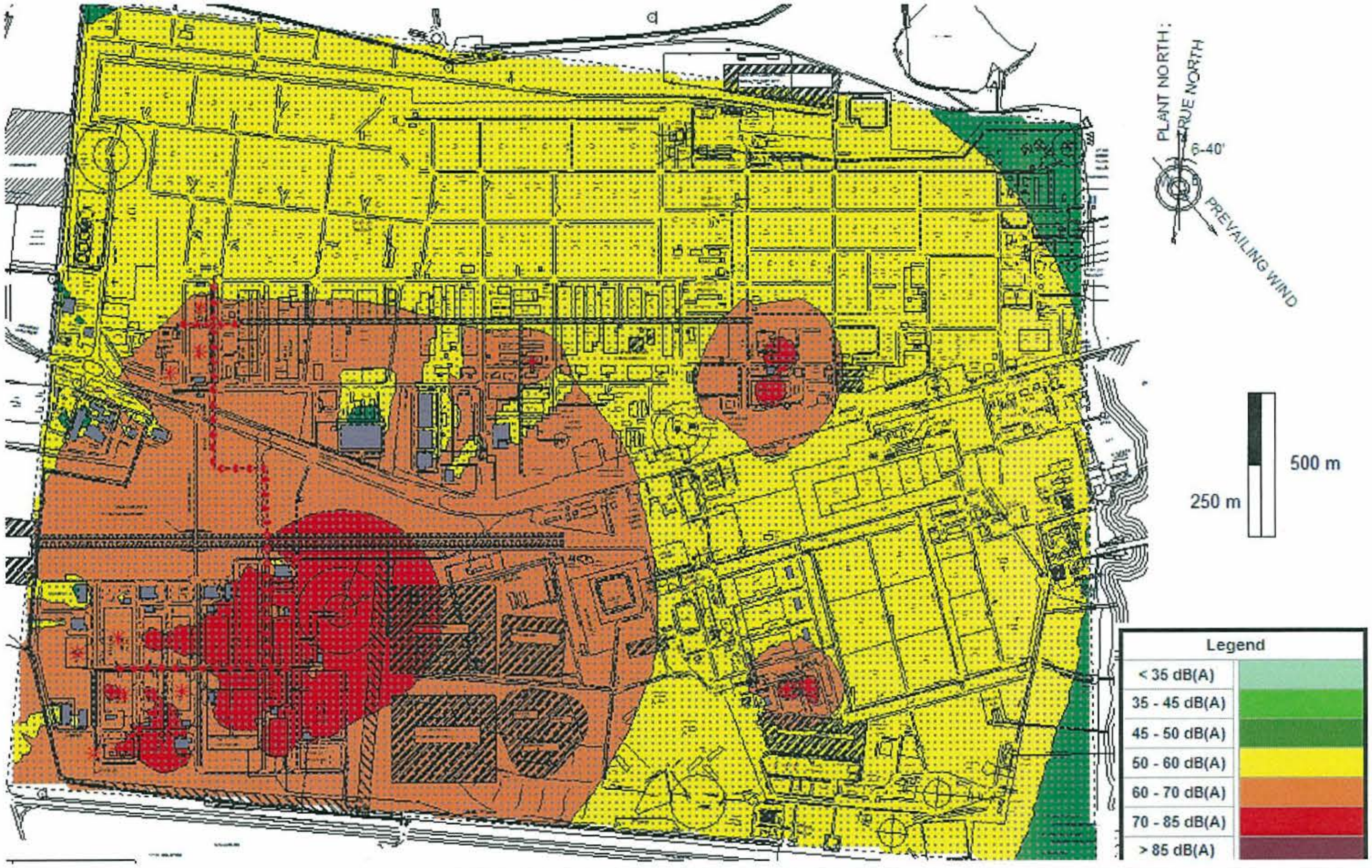
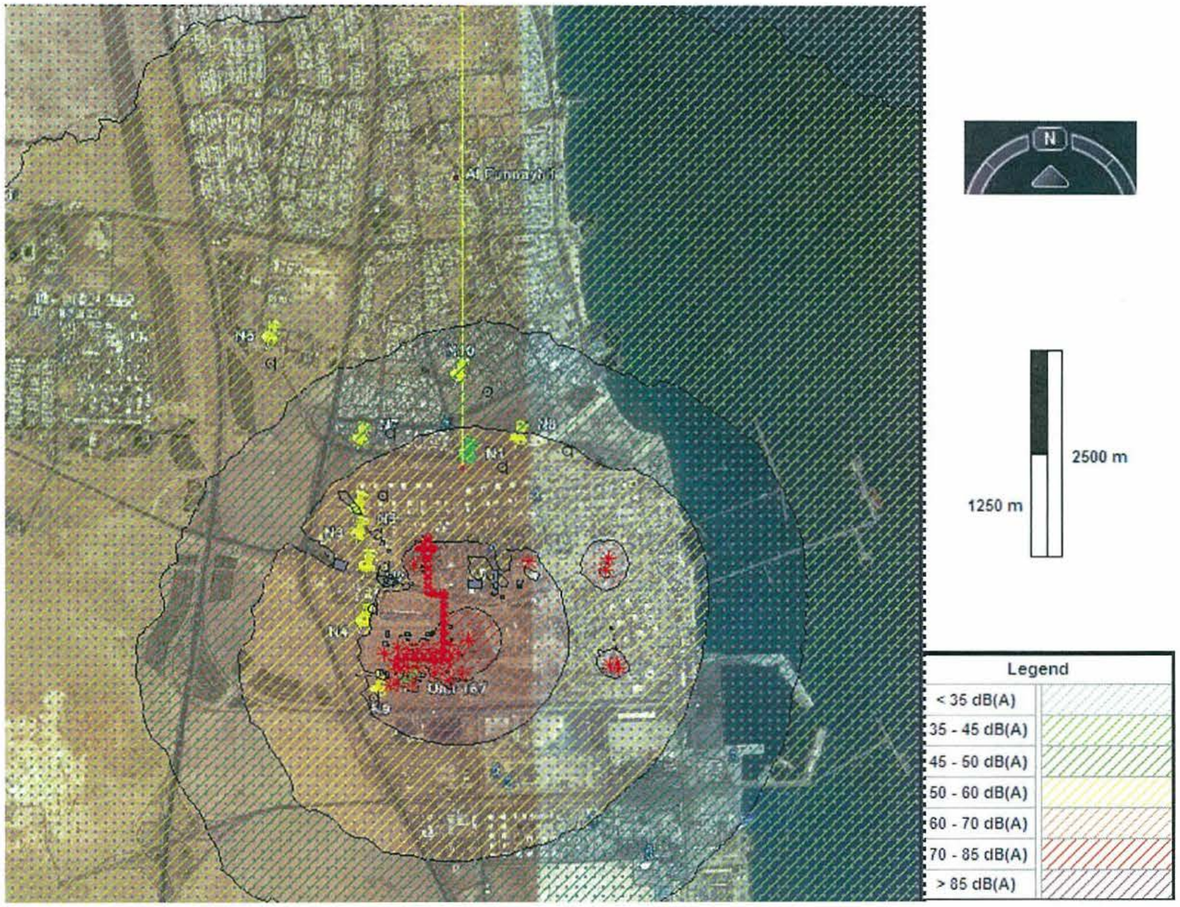


Figure 7P: Predicted Noise Levels for Operations Phase (Plant Upset Condition) - within MAA Area

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)



Based on the noise contours presented in Figure 7H through to Figure 7P, the maximum distances from the MAA CFP Block to various noise contour levels are identified and summarised in the following table.

Table 7.8: Noise Impact Prediction for MAA CFP

Predicted Noise Level[#] (Leq)	Maximum Distance from Fence Line of MAA CFP Block		
	Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
70 dB(A)	0 m	0 m	0 m
65 dB(A)	56 m [West]	0 m	70 m [South]
60 dB(A)	187 m [West]	0 m	440 m [South]
55 dB(A)	513 m [West]	230 m [South]	930 m [South]
50 dB(A)	1090 m [West]	865 m [South]	1690 m [South]
45 dB(A)	2068 m [West]	1780 m [South]	2910 m [South]

[#] Not including the existing background noise levels.

As seen from the above table, the most stringent community noise level of 45 dB(A) for night time L_{eq} in the ideal residential area will be reached at a maximum distance of 2910 m from the fence line of MAA CFP Block under the worst scenario (Operations Phase – Plant Upset Condition).

The predicted noise levels at selected receptors where background noise levels were monitored as part of baseline study are summarised in the following table (excluding baseline conditions)

Table 7.9: Predicted Noise Levels at Selected Receptors in MAA Area

Location ID	Location Description	Area Classification	Predicted L_{eq} in dB(A)		
			Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
N1 (MAA)	Near Busy Road	Residential (affected by traffic)	44.5	46.7	52.3
N2 (MAA)	Near Main-gate, Car Park & Flare	Industrial	46.3	50.3	58.9
N3 (MAA)	Near Flare/Road	Industrial	45.9	47.1	52.9
N4 (MAA)	Near Busy Road / Flare Sound in Background	Industrial	58.0	51.5	59.9

Location ID	Location Description	Area Classification	Predicted L_{eq} in dB(A)		
			Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
N5 (MAA)	Near Flare (Continuous & Strong Flare Sound)	Industrial	42.1	45.8	53.5
N6 (Offsite)	Close to Major Highway & Mosque (Continuous Traffic Noise)	Residential (affected by traffic)	40.2	38.8	43.3
N7 (MAA)	Near Busy Road (Traffic Signal & Highway), Workshops & Working Machinery	Residential (affected by traffic)	41.6	42.9	48.8
N8 (MAA)	Lamp Post Opposite to Tank 758	Residential	41.9	46.5	50.4
N9 (MAA)	Near Road	Industrial	63.5	55.4	62.0
N10 (Offsite)	Near Busy Road (Working Machinery)	Residential (affected by traffic)	41.9	43.9	48.0

Note: The results presented for the Construction Phase represent the case where the construction footprint within the CFP Block is located closest to the sensitive community receptors.

7.6.3 MAB Refinery Site

The predicted noise contours for Scenarios MAB 1 (Operations Phase - Normal Plant Operation), MAB 2 (Operations Phase - Plant Upset Condition) and MAB 3 (Construction Phase) are shown in the following figures. It should be noted that the noise values shown are for any time of the day, expressed as SPL in dB(A) and do not include the background noise levels. The effect of the background noise levels on the predicted values is discussed later in Section 7.7.1.

Figure 7Q: Predicted Noise Levels for Construction Phase (Site Preparation & Earthworks) – within MAB CFP Block

(Note: Background noise levels are not included. Site Preparation & Earthworks stage represents the worst case with respect to noise generation during the Construction Phase.)

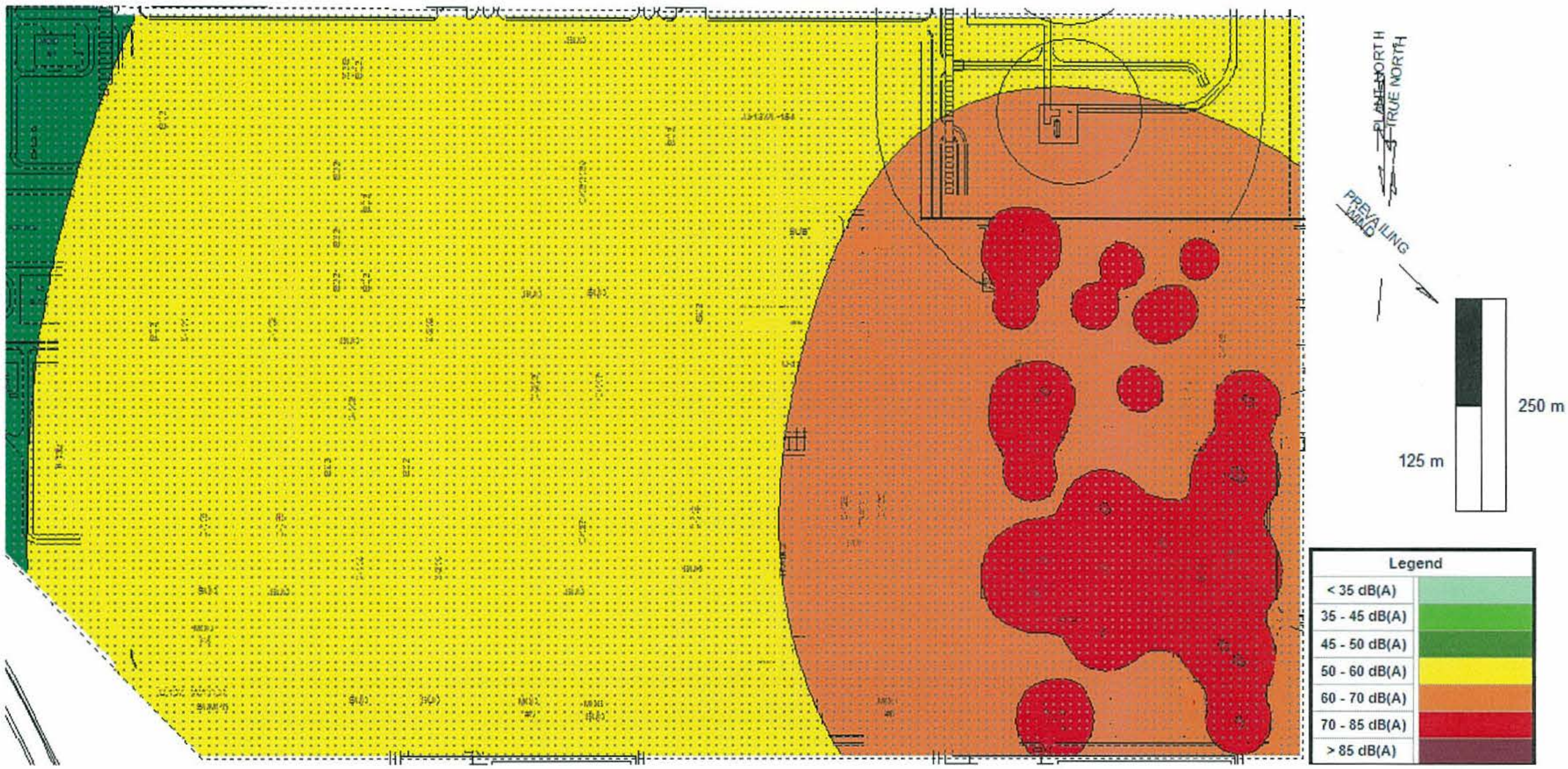


Figure 7R: Predicted Noise Levels for Construction Phase (Site Preparation & Earthworks) – within MAB Refinery Site

(Note: Background noise levels are not included. Site Preparation & Earthworks stage represents the worst case with respect to noise generation during the Construction Phase.)

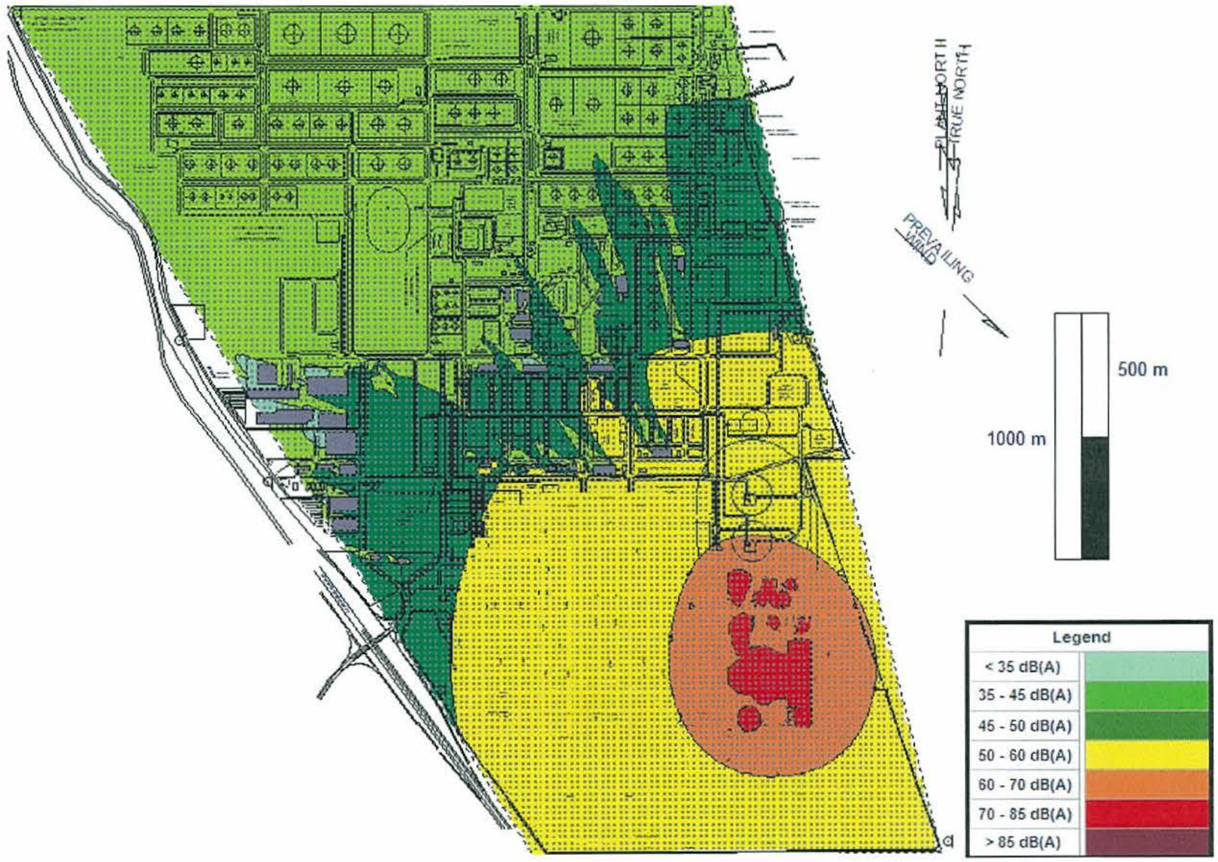


Figure 7S: Predicted Noise Levels for Construction Phase (Site Preparation & Earthworks) – within MAB Area

(Note: Background noise levels are not included. Site Preparation & Earthworks stage represents the worst case with respect to noise generation during the Construction Phase.)

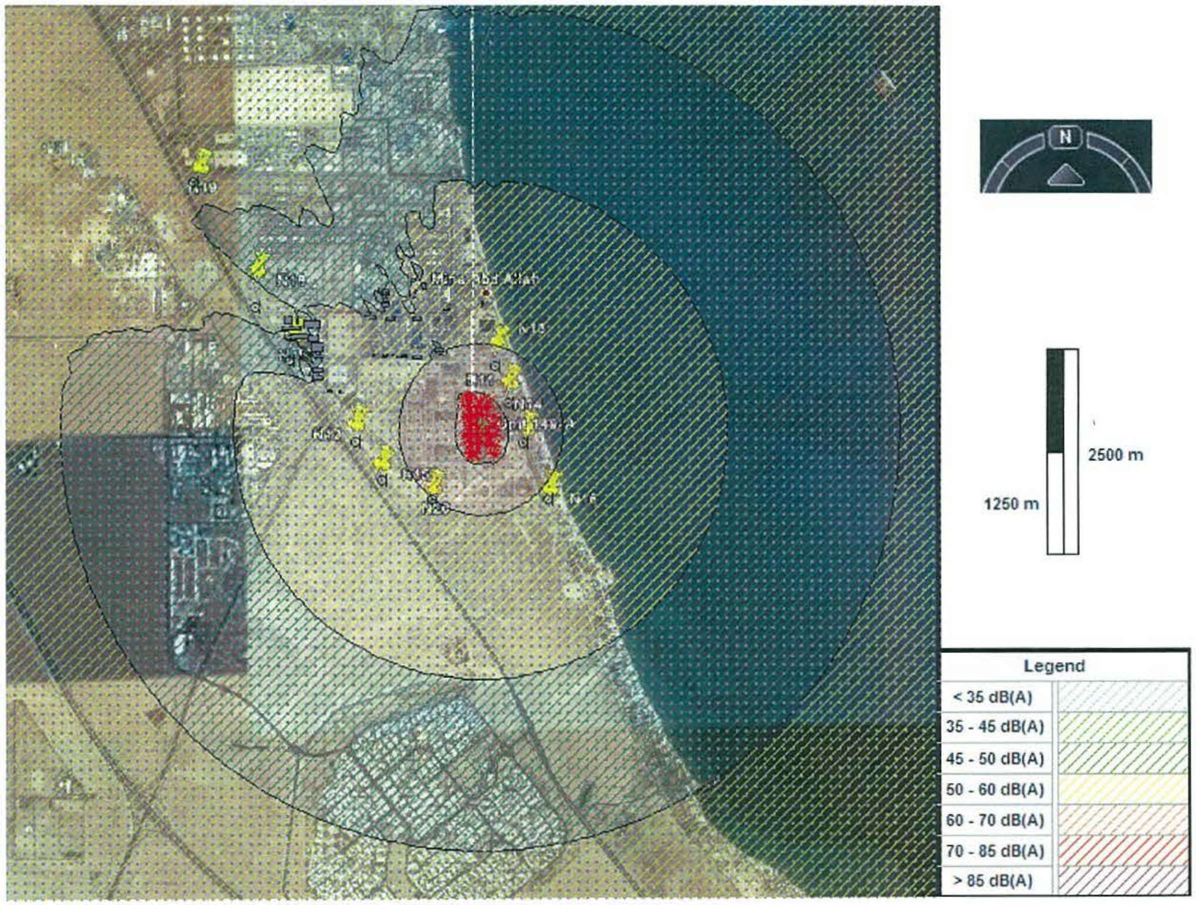


Figure 7T: Predicted Noise Levels for Operations Phase (Normal Plant Operation) – within MAB CFP Block

(Note: Background noise levels are not included. Under normal plant operation, flaring is at the minimal and flare noise is at the lowest.)

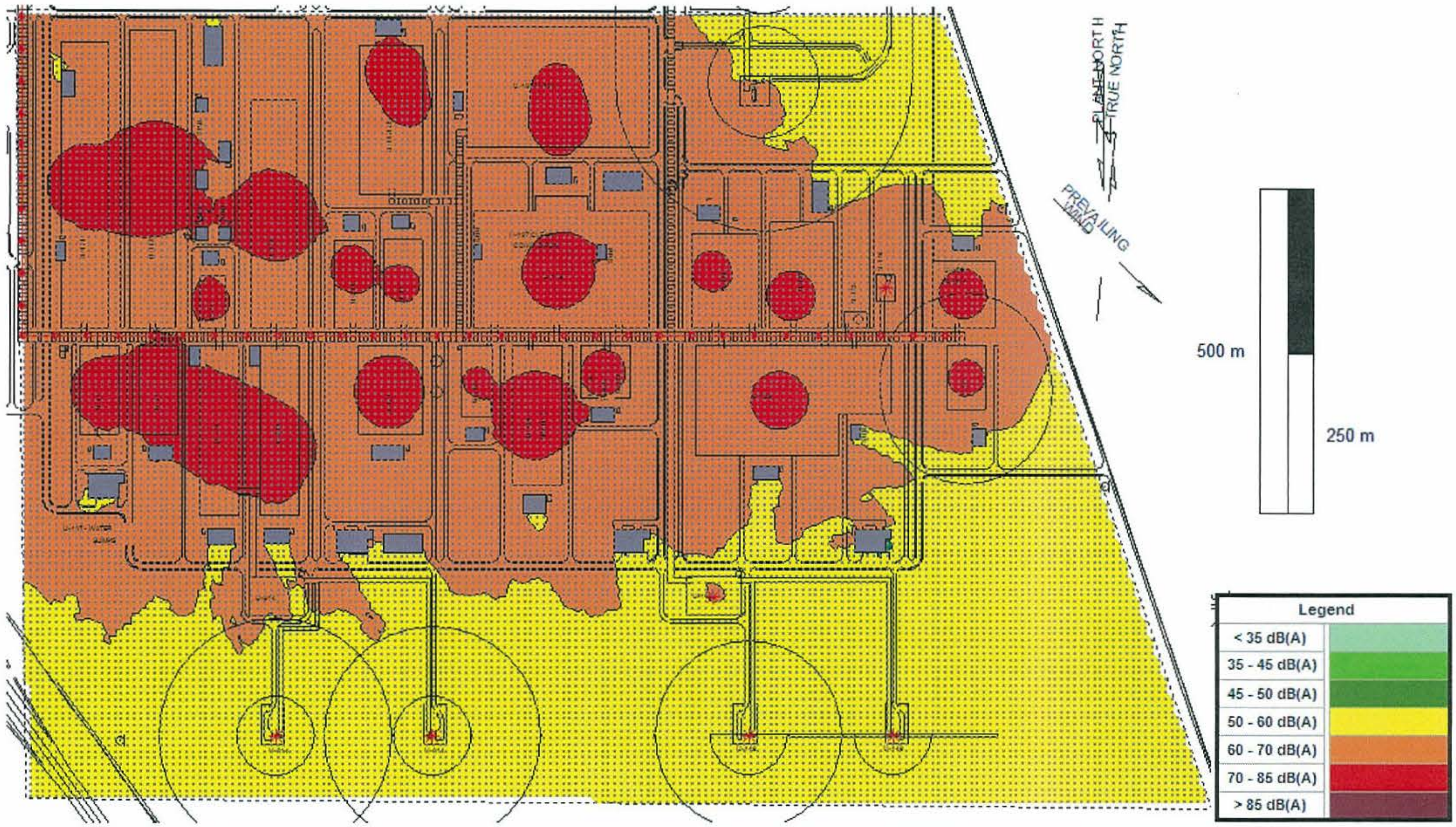


Figure 7U: Predicted Noise Levels for Operations Phase (Normal Plant Operation) – within MAB Refinery Site

(Note: Background noise levels are not included. Under normal plant operation, flaring is at the minimal and flare noise is at the lowest.)

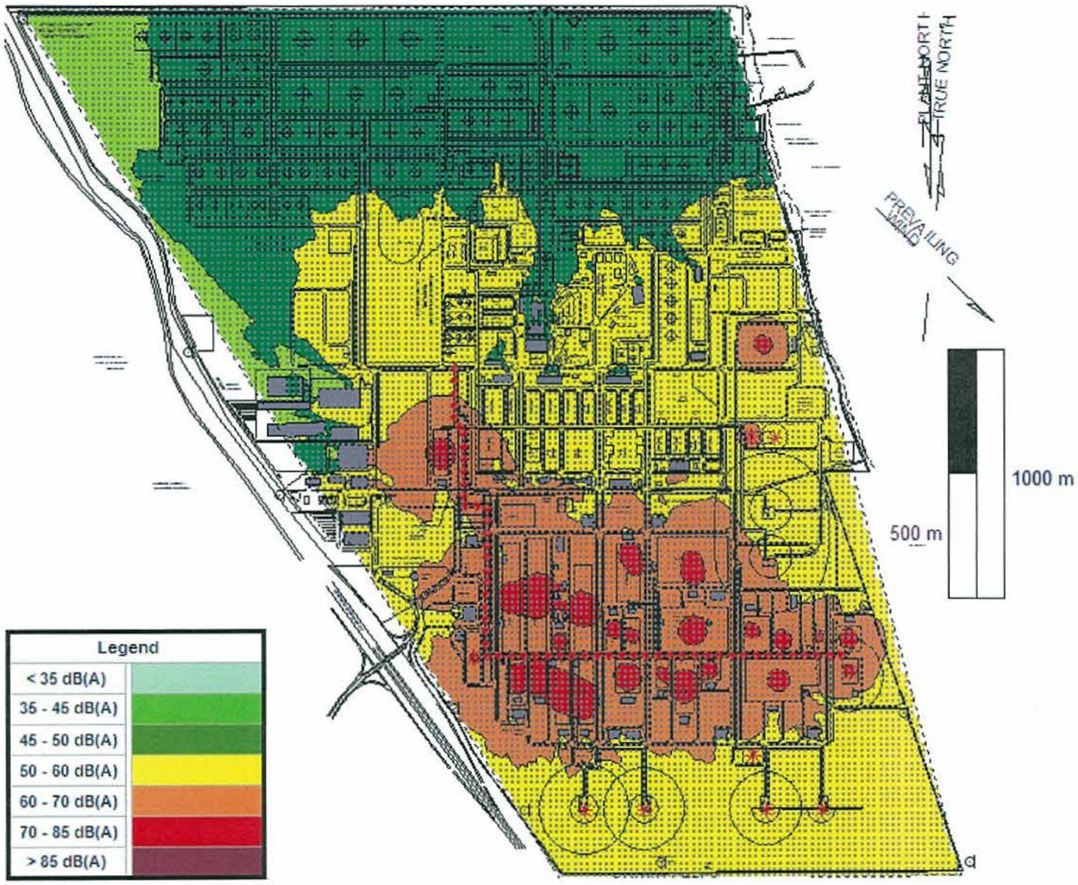


Figure 7V: Predicted Noise Levels for Operations Phase (Normal Plant Operation) – within MAB Area

(Note: Background noise levels are not included. Under normal plant operation, flaring is at the minimal and flare noise is at the lowest.)

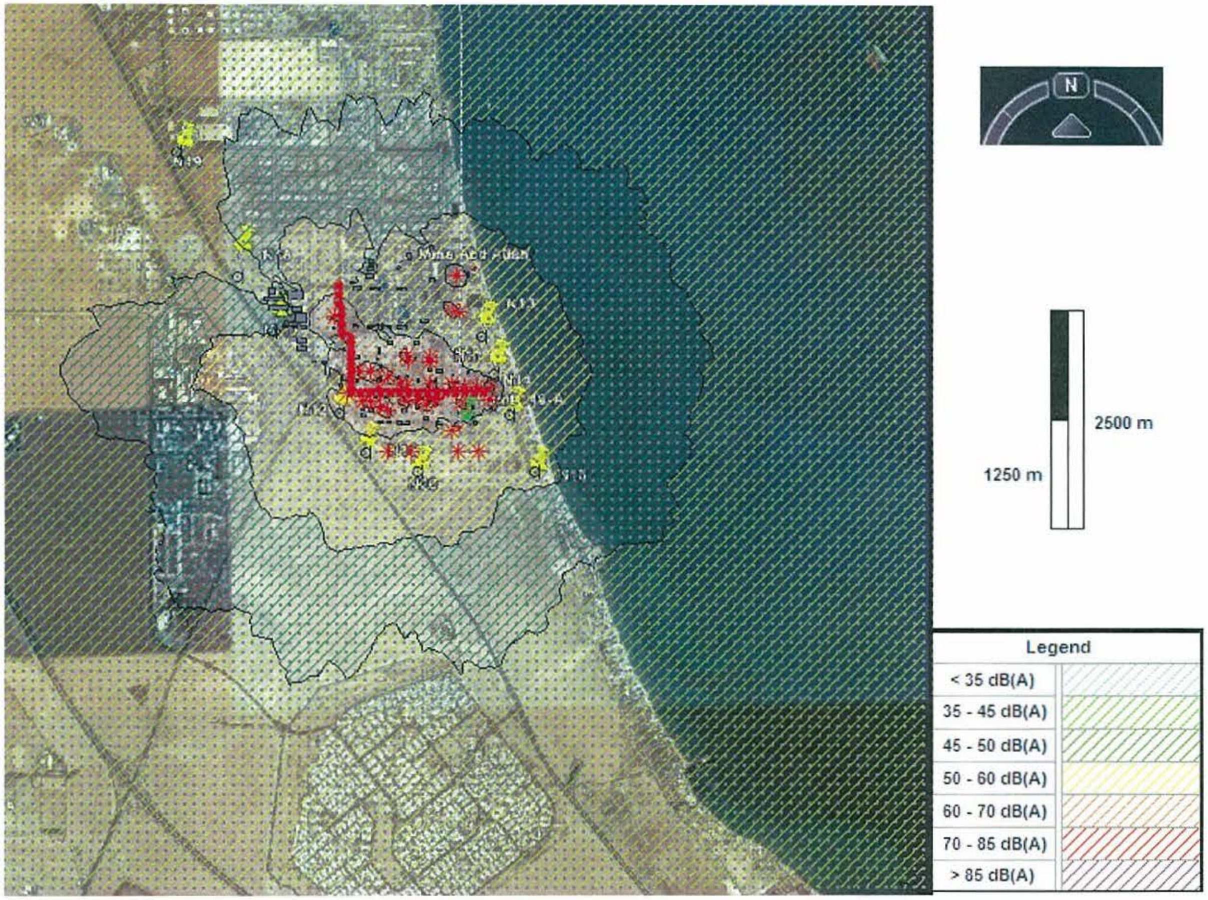


Figure 7W: Predicted Noise Levels for Operations Phase (Plant Upset Condition) – within MAB CFP Block

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)

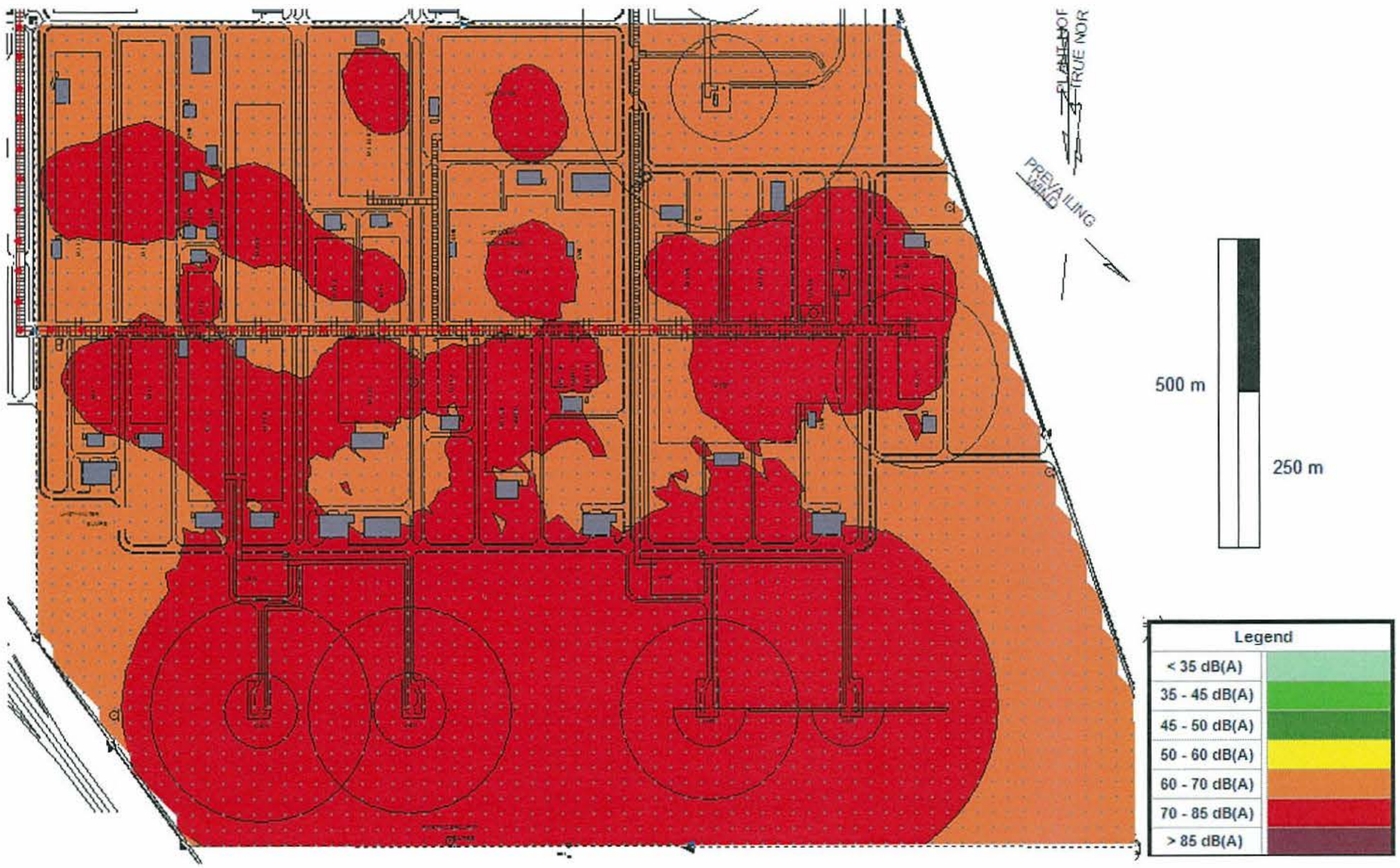


Figure 7X: Predicted Noise Levels for Operations Phase (Plant Upset Condition) – within MAB Refinery Site

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)

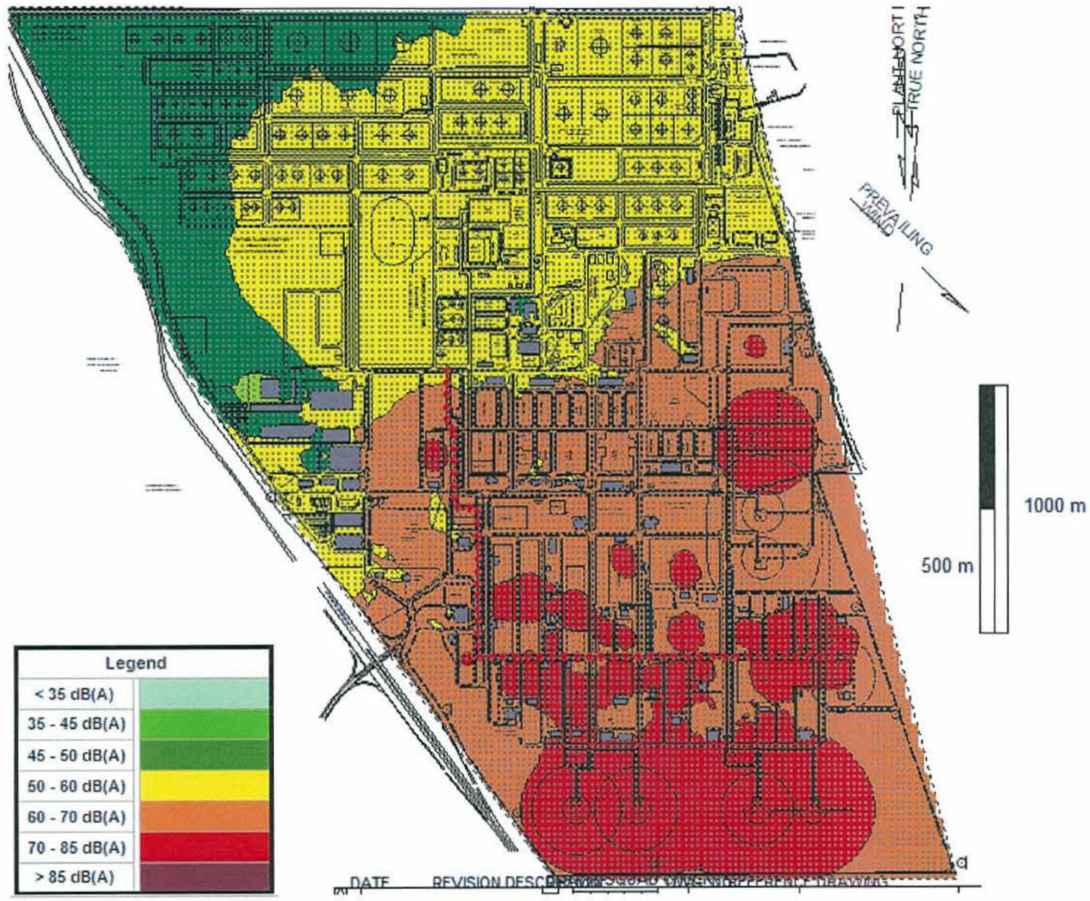
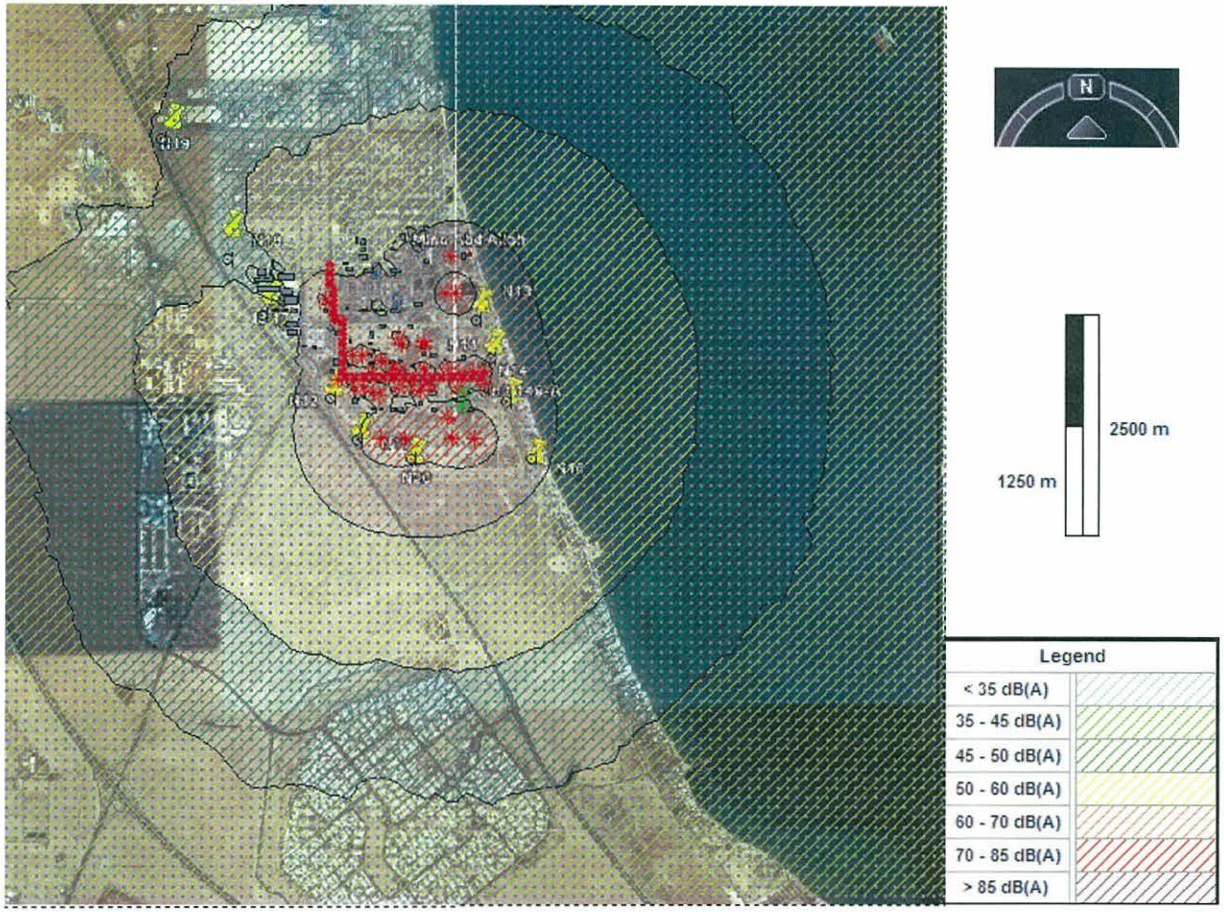


Figure 7Y: Predicted Noise Levels for Operations Phase (Plant Upset Condition) – within MAB Area

(Note: Background noise levels are not included. Under plant upset condition, flaring is at the maximum at design rating and flare noise is at the highest.)



Based on the contour maps shown in Figure 7Q, 7R, 7S, the maximum distances from the fence line of CFP Block in MAB to various noise contour levels are identified as summarised in the following table.

Table 7.10: Noise Impact Prediction for MAB CFP

Predicted Noise Level[#] (Leq)	Maximum Distance from Fence Line of CFP Block in MAB		
	Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
70 dB(A)	0 m	0 m	42 m [South]
65 dB(A)	0 m [East]	0 m	345 m [South]
60 dB(A)	30 m [East]	0 m	680 m [South]
55 dB(A)	380 m [East]	460 m [West]	1215 m [South]
50 dB(A)	950 m [East]	1200 m [South West]	2090 m [East]
45 dB(A)	1980 m [East]	2460 m [South West]	3500 m [South]

[#] Not including the existing background noise levels.

As seen from the above table, the most stringent community noise level of 45 dB(A) for night time L_{eq} in the ideal residential area will be reached at a maximum distance of 3500 m from the fence line of CFP Block under the worst scenario (Plant Upset Condition).

The predicted noise levels at selected receptors where background noise levels were monitored as part of baseline study are summarised in the following table (excluding baseline conditions).

Table 7.11: Predicted Noise Levels at Selected Receptors in MAB Area

Location ID	Location Description	Area Classification	Predicted L_{eq} in dB(A)		
			Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
N11 (MAB)	Near KNPC Units (Background Noise from Birds)	Residential	60.0	60.9	68.8
N12 (MAB)	Near Road	Industrial	48.9	61.9	65.0
N13 (MAB)	Near KNPC Units (Construction Work)	Residential	55.4	55.5	67.1

Location ID	Location Description	Area Classification	Predicted L_{eq} in dB(A)		
			Construction Phase (Site Preparation and Earthworks)	Operations Phase (Normal Plant Operation)	Operations Phase (Plant Upset Condition)
N14 (MAB)	Near KNPC Units	Residential	58.5	55.5	66.5
N15 (MAB)	Near Busy Road and Working KNPC Units	Industrial	49.9	56.7	70.0
N16 (MAB)	Near Villas (Birds & Knocking Sounds in the Background)	Residential	51.9	50.9	62.9
N17 (MAB)	Near Busy Road (Garage and Working Crane)	Industrial	39.7	49.6	53.6
N18 (MAB)	Near Busy Road and Working KNPC Units (Aeroplane Flying in the Background)	Industrial	35.8	43.6	48.7
N19 (MAB)	Near Busy Road (Cranes Working Nearside)	Industrial	37.3	42.3	45.5
N20 (MAB)	Far from Working KNPC Units	Industrial	52.5	54.5	71.4

Note: The results presented for the Construction Phase represent the case where the construction footprint within the CFP Block is located closest to the community receptors.

7.6.4 SHU Refinery Site

As discussed in Sections 7.4.1 and 7.4.4, noise modelling was not performed for the SHU Refinery Site, since following construction of the CFP facilities, the existing noise levels in this location will be reduced. The impact is, therefore positive (beneficial).

7.7 Noise Impact Evaluation

7.7.1 Predicted Impact from CFP Construction & Operation

The noise levels predicted through modelling for all of the scenarios considered in this study (refer Sections 7.6.2 and 7.6.3) do not include the existing background noise levels. Data on existing background noise levels are available at 20 selected locations of community interest (refer to Table 7.2). In order to determine the impact of community noise due to the noise generated from CFP construction and operation, the background noise levels are superposed on the predicted noise levels, and overall noise levels are determined and as discussed in the following sections.

Construction Phase

The predicted community noise impact for the Construction Phase is presented in the following table. It is to be noted that, there will normally be no night time impacts during the Construction Phase since the considered construction activities (Site

Preparation and Earthworks Phase) will not be performed during the night time expect under exceptional situations.

Table 7.12: Predicted Community Noise Impact at MAA and MAB Areas – Construction Phase

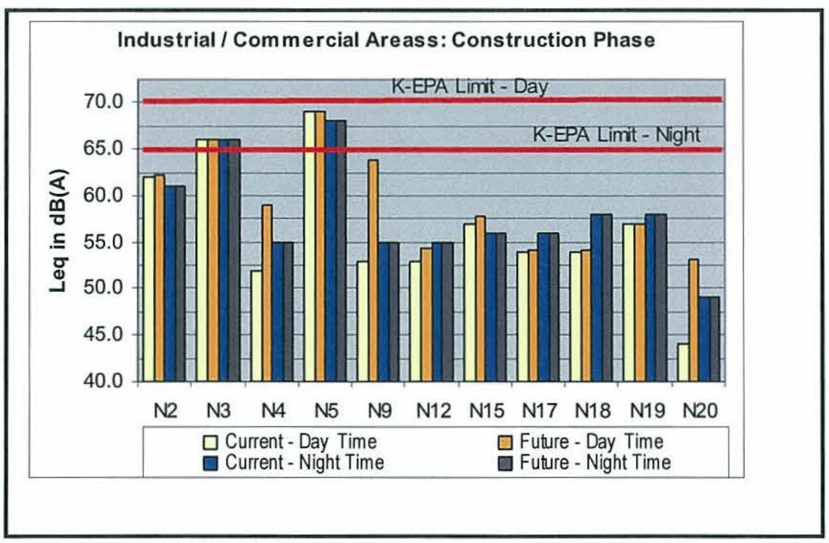
Location ID	Area Classification	Maximum Permissible Noise Levels in dB(A) (K-EPA Standards)	Worst Case L_{eq} in dB(A)				
			Predicted Noise Level due to CFP (Day)	Current Background Level (Measured)		Predicted Future Noise Level (Overall)	
				Day	Night	Day	Night
N1 (MAA)	Residential (affected by traffic)	Day: 65 Night: 60	44.5	55	52	55.4	No change
N2 (MAA)	Industrial	Day: 70 Night: 65	46.3	62	61	62.1	No change
N3 (MAA)	Industrial	Day: 70 Night: 65	45.9	66	66	66.0	No change
N4 (MAA)	Industrial	Day: 70 Night: 65	58	52	55	59.0	No change
N5 (MAA)	Industrial	Day: 70 Night: 65	42.1	69	68	69.0	No change
N6 (Offsite)	Residential (affected by traffic)	Day: 65 Night: 60	40.2	51	51	51.3	No change
N7 (MAA)	Residential (affected by traffic)	Day: 65 Night: 60	41.6	60	57	60.1	No change
N8 (MAA)	Residential	Day: 60 Night: 50	41.9	53	50	53.3	No change
N9 (MAA)	Industrial	Day: 70 Night: 65	63.5	53	55	63.9	No change
N10 (Offsite)	Residential (affected by traffic)	Day: 65 Night: 60	41.9	54	53	54.3	No change
N11 (MAB)	Residential	Day: 60 Night: 50	60	50	50	60.4	No change
N12 (MAB)	Industrial	Day: 70 Night: 65	48.9	53	55	54.4	No change
N13 (MAB)	Residential	Day: 60 Night: 50	55.4	55	55	58.2	No change
N14 (MAB)	Residential	Day: 60 Night: 50	58.5	45	45	58.7	No change
N15 (MAB)	Industrial	Day: 70 Night: 65	49.9	57	56	57.8	No change
N16 (MAB)	Residential	Day: 60 Night: 50	51.9	46	49	52.9	No change

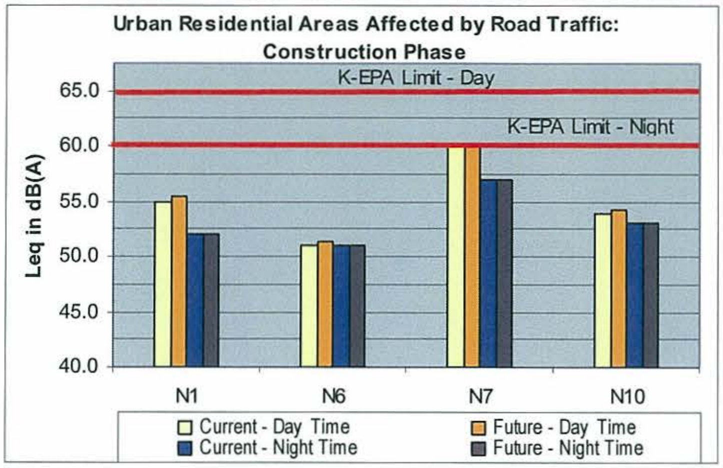
Location ID	Area Classification	Maximum Permissible Noise Levels in dB(A) (K-EPA Standards)	Worst Case L_{eq} in dB(A)				
			Predicted Noise Level due to CFP (Day)	Current Background Level (Measured)		Predicted Future Noise Level (Overall)	
				Day	Night	Day	Night
N17 (MAB)	Industrial	Day: 70 Night: 65	39.7	54	56	54.2	No change
N18 (MAB)	Industrial	Day: 70 Night: 65	35.8	54	58	54.1	No change
N19 (MAB)	Industrial	Day: 70 Night: 65	37.3	57	58	57.0	No change
N20 (MAB)	Industrial	Day: 70 Night: 65	52.5	44	49	53.1	No change

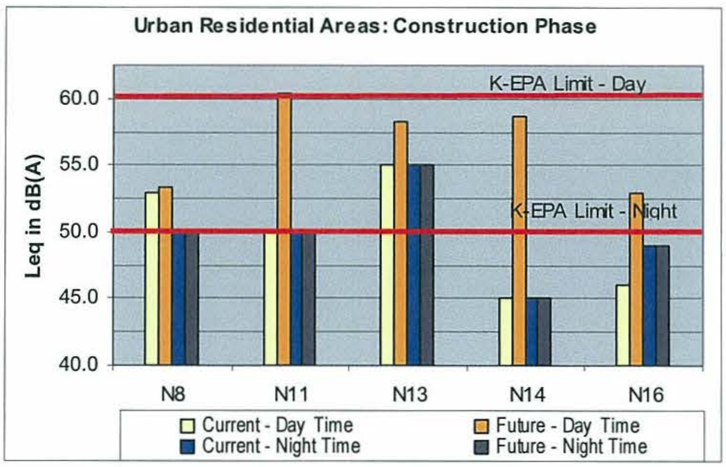
Note: The values exceeding the relevant K-EPA community noise standards (refer Table 7.1.) are highlighted in orange for the baseline noise levels and in red for the predicted future noise levels.

The above results are graphically presented in the following figure.

Figure 7Za: Predicted Community Noise Impact at MAA and MAB Areas – Construction Phase







As seen from the above table, the current (baseline) noise levels have already reached or exceeded the relevant K-EPA standards during the night time at two industrial receptors (N3 and N5) and at three residential receptors (N8, N11 and N13), although no exceedence is observed during the day time at any receptor.

With regard to the future noise levels, a minor exceedence of the relevant K-EPA standard is predicted during the day time for N11 (60.4 dB(A)). Moreover, daytime noise levels do increase at sensitive residential receptors N4, N9, N11, N14, N16 and N20 as a result of CFP construction, but do not exceed the K-EPA relevant standard.

The night time noise levels remain unaffected during the Construction Phase since the considered type of construction activities will not be carried out during the night time, except under exceptional situations.

Operations Phase (Normal Plant Operation)

The predicted community impact for the Operations Phase under normal plant operation is presented in the following table. Under normal operation, the flaring will be minimal and consequently the noise generated from the flares will also be minimal.

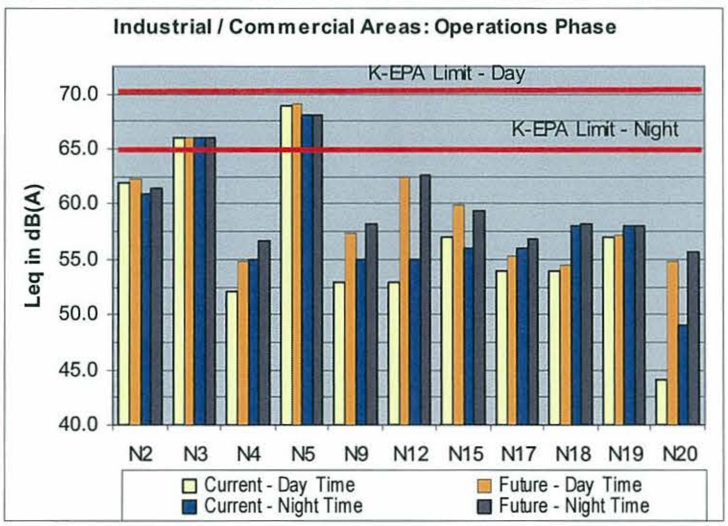
Table 7.13: Predicted Community Noise Impact in MAA & MAB Areas Operations Phase (Normal Plant Operation)

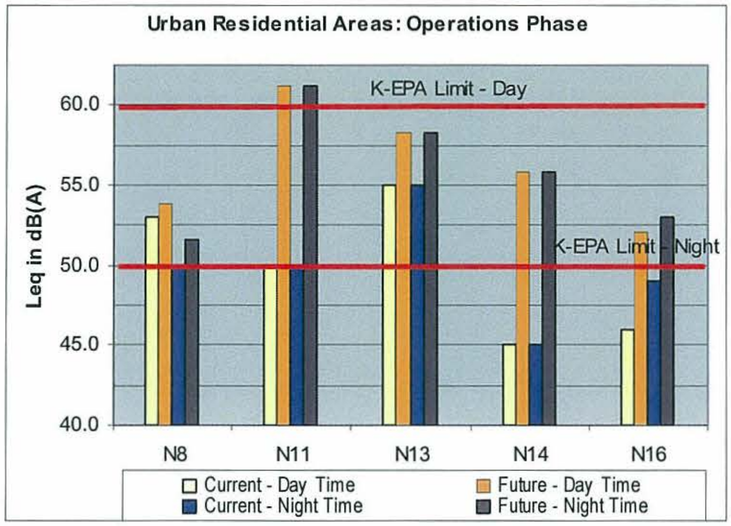
Location ID	Area Classification	Maximum Permissible Noise Levels in dB(A) (K-EPA Standards)	L_{eq} in dB(A)				
			Predicted Noise Level due to CFP (Day or Night)	Current Background Level (Measured)		Predicted Future Noise Level (Overall)	
				Day	Night	Day	Night
N1 (MAA)	Residential (affected by traffic)	Day: 65 Night: 60	46.7	55	52	55.6	53.1
N2 (MAA)	Industrial	Day: 70 Night: 65	50.3	62	61	62.3	61.4
N3 (MAA)	Industrial	Day: 70 Night: 65	47.1	66	66	66.1	66.1
N4 (MAA)	Industrial	Day: 70 Night: 65	51.5	52	55	54.8	56.6
N5 (MAA)	Industrial	Day: 70 Night: 65	45.8	69	68	69.0	68.0
N6 (Offsite)	Residential (affected by traffic)	Day: 65 Night: 60	38.8	51	51	51.3	51.3
N7 (MAA)	Residential (affected by traffic)	Day: 65 Night: 60	42.9	60	57	60.1	57.2
N8 (MAA)	Residential	Day: 60 Night: 50	46.5	53	50	53.9	51.6
N9 (MAA)	Industrial	Day: 70 Night: 65	55.4	53	55	57.4	58.2
N10 (Offsite)	Residential (affected by traffic)	Day: 65 Night: 60	43.9	54	53	54.4	53.5
N11 (MAB)	Residential	Day: 60 Night: 50	60.9	50	50	61.2	61.2
N12 (MAB)	Industrial	Day: 70 Night: 65	61.9	53	55	62.4	62.7
N13 (MAB)	Residential	Day: 60 Night: 50	55.5	55	55	58.3	58.3
N14 (MAB)	Residential	Day: 60 Night: 50	55.5	45	45	55.9	55.9
N15 (MAB)	Industrial	Day: 70 Night: 65	56.7	57	56	59.9	59.4

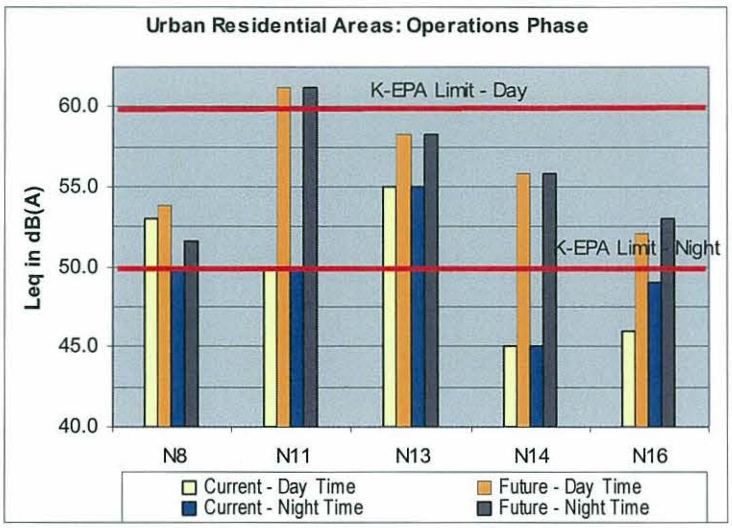
Location ID	Area Classification	Maximum Permissible Noise Levels in dB(A) (K-EPA Standards)	L_{eq} in dB(A)				
			Predicted Noise Level due to CFP (Day or Night)	Current Background Level (Measured)		Predicted Future Noise Level (Overall)	
				Day	Night	Day	Night
N16 (MAB)	Residential	Day: 60 Night: 50	50.9	46	49	52.1	53.1
N17 (MAB)	Industrial	Day: 70 Night: 65	49.6	54	56	55.3	56.9
N18 (MAB)	Industrial	Day: 70 Night: 65	43.6	54	58	54.4	58.2
N19 (MAB)	Industrial	Day: 70 Night: 65	42.3	57	58	57.1	58.1
N20 (MAB)	Industrial	Day: 70 Night: 65	54.5	44	49	54.9	55.6

Note: The values exceeding the relevant K-EPA community noise standards (refer Table 7.1) are highlighted in orange for the baseline noise levels and in red for the predicted future noise levels.

Figure 7Zb: Predicted Community Noise Impact at MAA and MAB Areas – Operation







As noted earlier, the current (baseline) noise levels already reach or exceed relevant K-EPA standards during the night time at two industrial receptors (N3 & N5) and at three residential receptors (N8, N11 and N13), although no exceedence is observed during the daytime at any receptor.

With regard to the future noise levels, as seen from the above figure, minor exceedence of the relevant K-EPA standard is predicted during the day time at N11 (61.2 dB(A)) under normal plant operation. Moreover daytime noise levels do increase at some key sensitive residential receptors, N9, N11, N12, N14, N16 and N20 as a result of CFP operation.

For the night time noise however, minor to significant exceedences are predicted at five residential receptors (N8, N11, N13, N14 and N16) and two industrial receptors (N3 and N5).

The following points are noteworthy:

- At all the receptors where exceedence is predicted, the predicted night time noise levels are more or less the same as the predicted day time noise levels. (This is due to the fact that the baseline noise levels are more or less the same during the day and night at these receptors. This implies that community noise levels at these receptors are strongly influenced by the nearby industrial sources which hardly show any diurnal variation.)
- All receptors except N8 are located within 1000 m distance from the respective CFP site fence[4], while N8 which is about 1900 m away.
- Of all receptors where exceedence of criteria is predicted, at four receptors (N11, N13, N14 and N16) the exceedence is noticeable, that is the increase is more than 3 dB(A)[5].
- At the two industrial receptors where night time exceedence is predicted (N3 and N5), the current (baseline) night time noise levels have already exceeded the applicable community noise standard [65 dB(A)], apparently due to the noise from existing sources. The incremental rise due to the new noise sources is marginal.

Operations Phase (Plant Upset Condition)

The predicted noise levels without considering the baseline levels have been presented in Table 7.9 (for receptors N1 to N10) and in Table 7.11 (for receptors N11 to N20) for the Operations Phase under plant upset conditions. Under the plant upset operation, it is assumed that flaring will be at the maximum design flow rate resulting in the maximum SWL at source, while all other major plant equipment (the significant noise sources) would continue to operate as usual. Under such conditions, the predicted noise levels increase significantly (with reference to the normal plant operation) at receptors close to the flares – a maximum of 8.6 dB(A) at N2 receptor for MAA site and a maximum of 16.9 dB(A) at N20 receptor for MAB site.

However, this rise will not make any significant impact on the future noise level when the baseline noise levels are superposed, for the following reasons:

- The assumption that all process units continue to operate as usual during emergency flaring is overly conservative. During the power failure (which leads to emergency flaring), most of the process units will be shutdown and there is trade off between more flare noise and less process noise. Therefore in reality, there may not be any net rise in the noise levels at the receptors during emergency flaring.
- Emergency flaring occurs for only a short duration (an hour or less) for each occurrence, which will be followed by a period of several hours of virtually no noise from the process units and the flares. Since the community noise level is time-weighted over a period of 7 hours (7am to 2pm) for the day time and 6 hours (10pm to 4am) for the night time, any change in the time-weighted noise level at any receptor in reality would be negligibly small.

[4] For locations N1 to N10, the referred distance is with respect to the fence line of the CFP Block in MAA. For locations N11 to N20, the referred distance is with respect to the fence line of the CFP Block in MAB.
[5] Study's have shown that a change of less than 3 dB(A) in noise level is hardly noticed by most people, while a change of 6 dB(A) and above is quite obvious. A change of 10 dB(A) is considered significant.

7.7.2 Cumulative Impact from Concurrent External Projects

The cumulative impacts on the community noise from projects that are being developed concurrently are discussed in this section. With regard to the MAA Refinery Site, as discussed in Section 7.2.1, adjacent to and east of the CFP Block, three new projects FGTP, ERP and the proposed are for the 5th Train are being developed. No new projects were identified for consideration during the time of this writing at the MAB Refinery Site.

Since these projects are being designed and engineered by third parties, detailed information on these projects is not available. Consequently, based on limited information provided by KNPC, the following observations are made:

- The construction periods (particularly the civil works phase) of FGTP and ERP projects are not expected to coincide with that of the CFP. Therefore, no additional impact on community noise will occur.
- The noise contours for FGTP and ERP projects during the normal Operations Phase are not available. However, considering that these project sites are located farther from the community receptors when compared to the CFP Block of the MAA Refinery Site, it is likely that their impact will be marginal (<3 dB(A)).

7.8 Conclusions and Recommendations

7.8.1 Conclusions

Predicated on the results obtained from noise modelling based ISO 9613 method, the following conclusions are made with regard to the impact on community noise of CFP construction and operation at MAA and MAB sites:

(a) The contribution to community noise from CFP activities at both MAA and MAB is higher for the Construction Phase compared to the Operations Phase. The impact from construction activities is more at MAB than at MAA due to larger construction scope and footprint at MAB.

(b) The noise contour for 70 dB(A), which corresponds to maximum permissible day time community noise level in 'Industrial / Commercial Areas' ,will remain within the fence lines of CFP Block at both sites (MAA and MAB) and for both phases (construction and operations - not considering upset conditions).

(c) The noise contour for 60 dB(A), which corresponds to maximum permissible day time community noise level in 'Urban Residential Areas with Some Commercial Activities and Workshops, will remain within 680m distance from the fence lines of CFP Blocks at both sites and for both phases, when background noise is disregarded.

(d) The noise contour for 50 dB(A), which corresponds to maximum permissible day time community noise level in 'Ideal Residential Areas', will remain within 1610m distance from the fence lines of CFP Blocks at both sites and for both phases, when background noise is disregarded.

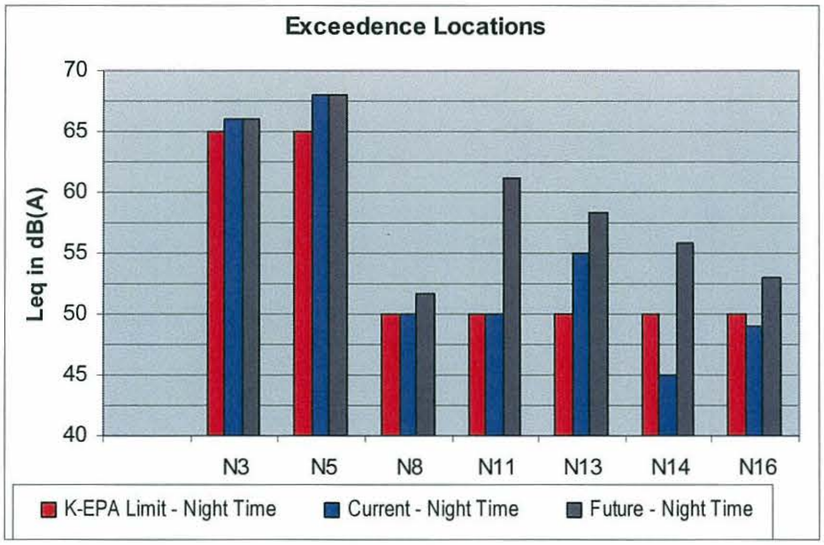
Out of the twenty receptors where the current (baseline) noise levels were measured, the night time levels have either reached or exceeded the relevant K-EPA standards at two industrial receptors (N3 and N5) and at three residential receptors (N8, N11 and N13). However, no exceedence is observed during the day time at any receptor.

When the current background noise levels are superposed on the predicted noise levels from the CFP construction and operation, the following conclusions are made:

(e) One case with minor exceedence with respect to the relevant K-EPA standard is predicted at N11 during the daytime. Moreover, there are noticeable noise increases at sensitive residential receivers N4, N9, N11, N12 N14, N16 and N20 and N20 during both CFP construction and operation during daytime.

(f) For the Construction Phase, night time noise levels will not be affected, since construction activities are not performed during the night hours except under very exceptional situations.

(g) For the Operations Phase, the night time noise levels are expected to exceed the relevant K-EPA standards at five residential receptors (N8, N11, N13, N14 and N16) and two industrial receptors (N3 and N5) as illustrated in the figure below.



(h) Of all receptors where exceedence of night time criteria is expected, at four receptors (N11, N13, N14 and N16) the exceedence is noticeable, that is the increase is more than 3 dB(A)

(i) At the 2 industrial receptors where night time exceedence is predicted (N3 & N5), the current night time background noise levels have already exceeded the applicable community noise standard [65 dB(A)] due to noise from existing sources (flares). The incremental rise due to the new CFP noise sources is marginal, and not deemed significant because there are no noise sensitive receivers at this area.

(j) All receptors except N8 are located within 1000 m distance from the respective site fence[6]. Receptor N8 which is about 1900m away from the respective site fence, and at this receptor the current noise level has already reached the maximum limit.

[6] For locations N1 to N10, the referred distance is with respect to the fence line of the CFP Site in MAA. For locations N11 to N20, the referred distance is with respect to the fence line of the CFP Site in MAB.

7.8.2 Recommendations

Based on the above, the following recommendations are made:

(a) Construction activities generating significant noise levels should not be carried out during the night time except under very exceptional situations. Otherwise, night time community noise levels may significantly breach the relevant K-EPA standards at residential locations close to the CFP sites.

(b) In order to fully comply with K-EPA community noise standards, additional noise attenuation using acoustic enclosures should be considered for significant noise emitting sources located close to the fence lines, particularly for CFP works near the eastern part of the CFP at MAB refinery.

(c) The process units where additional attenuation should be considered are U-123, U-125, U-129, U-146, U-149 and U-156. All these units are located in MAB CFP Block and they are close to the residential receptors N11, N13, N14 and N16 on the east side of the site. The additional attenuation required would be about 5 dB(A).

(d) Noise monitoring will be necessary during both construction and operation to ensure no significant impact upon receptors.

Observations:

(a) In the absence of vendor specifications for the SWL values for the equipment items, conservative values based on past experience were used in this study. Consequently, the predicted impacts are likely to be higher than actual. Therefore, noise modelling should be repeated after detailed equipment specifications are provided by the vendors in order to evaluate the need for further noise attenuation as indicated above.

(b) The results obtained from this study should not be used for the demarcation of noise hazard areas within the fence lines (workplace areas). In this study the numerous noise sources (i.e. equipment items) located within each individual unit at the CFP Block Sites are approximated to a single virtual point source. The consequence of this approximation is that the total area where SPL exceeds 85 dB(A)[7] is over-estimated. This approximation will however cause little error with regard to the community noise prediction.

[7] This is K-EPA's maximum permissible limit within workplace without ear protection.

8.0 Air Quality During Construction

8.1 Introduction

The most significant air contaminant potentially emitted during the construction phase of the CFP is dust (i.e. particulate matter). The US Environmental Protection Agency (EPA) describes dust as follows:

'Significant atmospheric dust arises from the mechanical disturbance of granular material exposed to the air. Dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. Common sources of fugitive dust include unpaved roads…aggregate storage piles, and heavy construction operations.

For the above sources of fugitive dust, the dust-generation process is caused by two basic physical phenomena:

- *pulverization and abrasion of surface materials by application of mechanical force through implements (wheels, blades, etc.)*
- *entrainment of dust particles by the action of turbulent air currents, such as wind erosion of an exposed surface by wind speeds over 19 km/h'.*

There will also be other air contaminants emitted during the construction phase of the CFP from activities such as cutting, welding, grinding and sand/shot blasting. The impacts of these are likely to be significantly less in comparison to dust, but they should still be considered.

This section provides an overview discussion of the potential issues associated with air pollutants released during the construction phase, with main focus on dust. It provides common sources of dust released typical to construction projects such as the CFP and details typical mitigation methods. This Chapter commits the CFP EPC contractors to develop Air Quality Management Plans during Construction.

8.2 Health Risks

Dust is a general name for minute solid particles with diameters less than 500 micrometers. The principal pollutant of interest in dust is PM10, particulate matter (PM) with no greater than 10 micrometers in aerodynamic diameter (µmA). Particulate Matter is a health risk, especially when small PM - e.g. PM10 – is inhaled.

Many studies have been conducted on the health risks of PM10. Larger particles are generally filtered in the nose and throat and do not cause problems, but particulate matter smaller than about 10 micrometres, can settle in the bronchi and lungs and cause health problems such as the exacerbation of chronic respiratory diseases e.g. asthma and bronchitis. If the dust is contaminated - e.g. dust released from demolition or the clean-up of contaminated land - the risk is significantly greater and can include lung cancer and cardiovascular issues.

However, the EBS suggests that any dust released from activities related to the CFP during its construction is generally not contaminated, apart from in isolated areas (these areas are addressed in Chapter 14).

8.3 Regulation in Kuwait

K-EPA'S Dust Pollution Division performs the following tasks:

- Monitoring and studying the daily and monthly rates of dust fall.
- Continuously monitoring air pollution and the different volatile organics in the residential, industrial and commercial areas, and other areas.
- Defining the sources of air pollutants, and assessing quantities.
- Suggesting control methodologies for each source of dust and volatile organics.
- Formulating necessary recommendations and regulations to protect humans from exposure to dangers of dust fall and suspended particulates.
- Preparing standard criteria & guidelines for air quality, and so specifying rates of emission from the different sources.
- Preparing monthly & annual reports about sources & rates of air pollution from dust & volatile particles.
- Preparing suggestions & plans in order to develop technology used in monitoring & measuring, as well as controlling, the air pollution of dust and volatile organic particles.

8.4 Sources and Control / Mitigation

There are several potential sources of fugitive dust releases during the construction phase of the CFP. They include the following:

- paved, and unpaved roads;
- cement mixing & batching;
- heavy construction operations;
- aggregate handling and storage piles.

Each of these sources is considered in the table below, with examples of control measures being provided. 'Best Available Control Techniques' (BACT) for specific sources cannot be provided at this stage of the project as control techniques will depend on the exact characteristics, extent and nature of the dust source. BACT will however, be used in the Air Quality Management Plan for managing specific sources of dust.

The CFP EPC contractors will each develop an Air Quality Management Plan using basic 'source - pathway – target' (i.e. receptor) methodology prior to and during the construction phase. This plan will be in accordance with any applicable K-EPA criteria and approved by KNPC.

Reducing the potential for dust to arise at source - i.e. preventative controls - should be employed as the most effective control and monitoring of dust at the site boundary and offsite should be an integral part of the plan.

The Air Quality Management Plan should also include control of other sources of air pollution during construction, including the use of the large numbers of Diesel Generator (DG) sets employed for welding, which have potential for creating low level air pollution.

Table 8.1 - Potential Sources of Air Pollutants and Various Control Techniques

	Source	Control
Paved roads	Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking area. They are due to: • direct emissions from vehicles in the form of exhaust emissions, • brake wear and tyre wear emissions, and • the re-suspension of loose material on the road surface. In general terms, re-suspended particulate emissions originate from, and result in the depletion of, loose material present on the surface. Surface loading of material is replenished by spillage of material and material carried from unpaved roads which could also be an issue on surrounding public roads.	Control techniques for paved roads attempt either to prevent material from being deposited onto the surface (*preventive controls*) in the first place, or the removal from the road of any material that has been deposited (*mitigation*). • *Preventative*: Covering loads in trucks, and paving of access areas to unpaved areas or construction sites. • *Mitigation*: Vacuum cleaning / sweeping, water-flushing, and broom-sweeping and under-chassis and wheel washing. The actual control efficiencies by any of these techniques vary.
Unpaved roads	The force of the wheels of vehicles travelling on unpaved roads causes pulverisation of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The main factor in the amount of particles released is particle size & moisture content. In arid regions such as the CFP site, moisture content of the underlying road surface is likely to be very low. Therefore the risk of significant dust release from unpaved roads is likely to be high.	A variety of options exist to control emissions from unpaved roads. These options fall into the following three groupings: • vehicle restrictions that limit the speed, weight or number of vehicles on the road; • surface improvements by measures such as (a) paving or (b) adding gravel or slag to a dirt road; • surface treatments such as watering or treatment with chemical dust suppressants.
Heavy Construction Operations	Heavy construction is a source of dust emissions that may have substantial temporary impact on local air quality. Building and road construction are two examples of construction activities with high emissions potential. Emissions during the construction of a project such as the CFP can be associated with: • land-clearing, • drilling, • ground excavation,	Each phase of construction can be broken down into specific stages which have a differing potential for dust generation and associated control measures: I. Demolition / debris removal II. Site preparation III. General Construction (earth moving) Control methods can be made suitable for each stage – for example: • Phase I - a combination of paved roads, and wet / chemical

	Source	Control
	• cut and fill operations (i.e. earth moving), and • the construction of a particular facility itself. Dust emissions can vary substantially from day to day, depending on the level of activity, specific operations, and prevailing meteorological conditions. The temporary nature of construction differentiates it from other fugitive dust sources as to estimation and control of emissions. Construction consists of a series of different operations, each with its own duration and potential for dust generation. However, in general, the quantity of dust emissions from construction operations is proportional to the area of land being worked and to the level of construction activity.	suppression could be used; • Phase II - as above but with the stockpiles covered with tarpaulins / wind reduction techniques to reduce wind blown dust (see below). In addition, the boundary fence could be designed to reduce windflow over the site and thus reduce the potential for wind-blown dust. During construction activities, water used as a dust suppressant will be applied, as necessary, in the construction area during grading, excavation, and earth-moving activities to control or reduce fugitive dust emissions. Application of water significantly reduces emissions.
Aggregate handling and storage piles	Construction activities on site are likely to use aggregates stored in outdoor storage piles. Storage piles are usually left uncovered, partially because of the need for frequent material transfer into or out of storage. Dust emissions can occur at several points in the storage cycle, such as: • material loading onto the pile, • disturbances by strong wind currents, and • loading trucks from the pile. The quantity of dust emissions from aggregate storage operations varies according to the volume of aggregate passing through the storage cycle. Emissions also depend on three storage pile condition parameters: • age of the pile, • moisture content, and • proportion of aggregate fines.	Watering and the use of chemical wetting agents are the principal means for control of aggregate storage pile emissions. However, in regions with high evaporation, construction site enclosure or covering of inactive piles to reduce wind erosion can also reduce emissions. Watering / chemical wetting agents are useful mainly to reduce emissions from vehicle traffic in the storage pile area. The use of water on the storage piles themselves typically has only a very temporary effect on total emissions. A much more effective technique, is to apply chemical agents (such as surfactants) that permit more extensive wetting. Continuous chemical treating of material loaded onto piles, coupled with watering or treatment of roadways can reduce total particulate emissions from aggregate storage operations by up to 90%.
Cutting, welding, grinding & blasting	General construction activities such as cutting, welding, blasting and grinding will have the potential to create low level air pollution from diesel generators. This pollution will likely be negligible in comparison to the dust pollution on site.	The control of this low level air pollution will be covered in the contractor Air Quality Management Plan. Control measures will include keeping diesel generator usage to a minimum.

8.5 Air Quality Management Plan / Risk Assessment

The potential impact of construction dust and other air pollution upon the surrounding environment was assessed using the matrix approach of DNV's impact assessment methodology (as discussed in Chapter 6). Figure 8A below displays the impact assessment and concludes that, provided a solid Air Quality Management Plan is developed by the EPC contractor and implemented, impacts from construction dust will be managed at a moderate negative impact. The Air Quality Management Plan will typically apply the sort of mitigation methods discussed for the various dust sources likely to occur. The Air Quality Management Plan will also include the control of other sources of air pollution during construction.

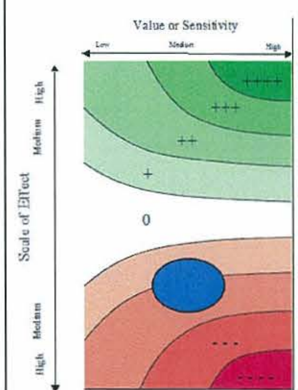
Figure 8A: Impact Matrix for Air Quality during Construction

<table>
<tr><td colspan="2">Category: Environment
Consequence evaluation for: Air Quality During Construction</td></tr>
<tr><td colspan="2">1. General description of the area (situation and characteristics)</td></tr>
<tr><td colspan="2">Note: This section describes the sensitivity of the area in question. Following a review of existing information regarding the site's sensitivity, a sensitivity rating or value is given.

There are some residential communities potentially downwind of the CFP site. There will also be a large construction workforce who will be susceptible to construction dust impacts. As the workforce shall be provided with protective equipment, the sensitivity is deemed Medium.

Low Medium High
|-- ---------X------------|</td></tr>
<tr><td>2. Description of the extent of effect</td><td>3. Total impact on environment</td></tr>
<tr><td>Evaluation of extent:

There is high potential for very negative effects as a result of construction dust if it is not managed in a strict and structured manner. This EIA commits EPC contractors to produce a solid Air Quality Management Plan based on the key elements set out in this chapter. Provided these are implemented, it is considered that the extent of construction dust effect will be managed at a medium negative effect.

Very neg. Medium neg. Little/no Medium pos. Very pos.
|--------------X---------------|---------------|------------------|</td><td>"Moderate negative impact"
</td></tr>
</table>

8.6 Conclusions

Based on available information, it is believed that dust released from activities related to the CFP during its construction will not be contaminated. Naturally occurring dust storms occur periodically and are expected to pose a greater threat to the health and safety of the workforce and local residents.

Most sources of dust which may be generated during the construction phase can readily be addressed by standard control measures. These control measures need to be **strictly** implemented for the impacts to be managed to a satisfactory level.

A strong Air Quality Management Plan, key elements of which have been set out above, will need to be implemented by the EPC contractors during the construction phase of the CFP in order to limit impacts to "medium negative impact". This plan will also need to cover other ambient air pollution sources during construction such as cutting, welding, grinding and blasting and control measures for these sources will be laid out in the Plan.

8.7 Recommendations

Provided the following recommendations are adopted, impacts upon air quality during construction can be managed satisfactorily.

It is recommended that:

- A rigorous Air Quality Management Plan be provided by the EPC contractors and be put into action.
- The Air Quality Management Plan should include some early commitment to provide temporary construction roads as soon as practicable to minimise dust releases.
- The EPC contractors ensure that appropriate mitigation measures are applied, both by themselves and their sub-contractors.
- The EPC contractors conduct ongoing monitoring for generation of dust across the CFP site throughout the construction phase.
- The EPC contractors ensure that appropriate mitigation measures are applied, both by themselves and their sub-contractors, for other sources of air pollution during construction such as welding, cutting, grinding and blasting.
- An experienced independent environmental professional should visit the site at least twice a week to ensure that these measures (and all other environmental management measures recommended in this EIS report) are being applied by EPC contractors.

9.0 Air Quality During Operation

9.1 Introduction

The operation of the CFP Project will "remove" significant quantities of air contaminants from the atmosphere primarily owing to the decommissioning of SHU Refinery, as well as generate air contaminant emissions to atmosphere from the new facilities at MAA and MAB refineries. The focus in this Chapter is on air quality and associated air emissions during CFP Operations Phase only. The key objective of this Chapter is to evaluate the overall effect that this project has on the air quality, and whether the resulting concentrations of various pollutants meet K-EPA / Ministry of Oil (*MOO*) criteria.

All the conclusions drawn in this Chapter assume that SHU is decommissioned at the same time as CFP new facilities are commissioned.

For construction-related air quality impacts, refer to Chapter 8 of this report.

The structure of this chapter includes:

- Discussion of baseline ambient air quality at the CFP site and its adjacent vicinity, both now and in the future (Section 9.2).
- Process releases during operations are discussed – point source, fugitive, emergency emissions, upset condition emissions and maintenance scenarios (Section 9.3).
- Discussion and information concerning the atmospheric dispersion modelling conducted by DNV, together with analysis of the results, and comparison against K-EPA / MOO criteria (Section 9.4)
- Analysis of VOC fugitive emissions (Section 9.4.6.7).
- Discussion on monitoring and sampling, which will be crucial in ensuring that the CFP's operations are conducted in compliance with K-EPA / MOO criteria (Section 9.5).
- Conclusions (Section 9.7).

Following start-up of the CFP's operations, point source emissions will primarily be generated by combustion-related equipment such as process heaters / furnaces / boilers, incineration systems, and flare systems (during emergency). In addition, the decommissioned point sources (primarily at the SHU refinery) will also impact the resulting air quality, both within the CFP's boundaries as well as the adjacent area of the site. The approach in this report is to combine the 'negative' effect of the new sources with the beneficial effect (in terms of air quality) of the decommissioned sources to obtain a representative estimate of the future air quality in the area after the completion of the CFP Project.

Fugitive emission sources will mainly include storage tanks, equipment components (such as valves, pumps, flanges, drains and compressors), port loading operations, sulphur-handling operations and wastewater treatment facilities.

The CFP incorporates good engineering practices, 'Best Available Control Technology' (BACT) and Environmental Management System (EMS) mechanisms that minimize or eliminate (where practical) atmospheric emissions, in compliance with K-EPA, and MOO air quality criteria (see Table 9.1, below):

Table 9.1: K-EPA air pollutant emissions standards from fixed sources

Source	Pollutant	Maximum allowed emissions
1. Industrial installations (all):		
1.1: All sources of emission	Suspended particulates	Smut (i.e. soot) must not exceed max. 20%
	Asbestos	No emissions allowed
1.2: Product piles	Suspended particulates	Smut (i.e. soot) must not exceed max. 20%
1.3: Chimneys	Suspended particulates	115 mg/m^3
	Opacity	Must not exceed max. 20%
2. Combustion facilities:		
Boilers and furnaces operated by mine fuel: thermal capacity >30MW (100 MBTU / hr)	Suspended particulates	43 ng/Joule
	SO_2	512 ng/Joule
	NOx	86 ng/Joule (for natural gas burning facilities)
	NOx	130 ng/Joule (for oil burning facilities)
	Opacity	Must not exceed max. 20%
3. Oil refineries:		
3.1 Burning systems or boilers used with FCCU	Suspended particulates	1 kg/tonne of charcoal to be burnt
	SO_2	9.8 kg/tonne of charcoal to be burnt
	CO	500 ppm
	Opacity	30% (except 6 minutes per hour)
3.2 Gas fuel burning operations	H_2S	230 mg/m^3 (dry)
3.3 Claus sulphur retrieval units (> 20 tonnes / day capacity)	SO_2	250 ppm for oxidization, reduction and burning activities
4. Liquid petroleum / organic volatile liquids storage tanks:		
4.1 Petroleum liquids tanks (1000 barrel capacity)	VOCs	Liquid at steam pressure ranging between 78/570mm Hg can be kept in tanks having floating or fixed ceilings (with internal floating cover or steam recall system). Emissions rate must remain at 95% or its equivalence.
4-2 Tanks of volatile organic liquids, including petroleum liquids tanks of > 1000 barrel capacity (where actual steam pressure is between 39-570 mm Hg), or of 500 barrels capacity (where steam pressure is between 207-570 mm Hg).	VOCs	Tanks must be provided with recall systems and steam must be relieved, so that emission rate should be 95% or its equivalence.
4-3 Fuel tanks of more than 500 barrel capacity (and steam pressure > 570 mm Hg).	VOCs	Tanks must be provided with fixed ceilings having floating internal cover, or it must be provided with floating ceilings of close ventilation. Further, tanks must be supplied with a system for relieving steam so that emissions must be reduced by 95% minimum or equivalence.
4-4 Fuel tanks >1000 barrel capacity (& steam pressure <24 mm Hg), or 500 barrel capacity (& steam pressure > 116 mm Hg).	VOCs	Tanks must be provided with closed ventilation system to relieve steam pressure, so that emissions must be reduced by 95% minimum.

Note: Source Appendix No.20. K-EPA

Stack height will be based upon good engineering practices to ensure optimal dispersion of air contaminants. For the majority of the new units installed as part of the CFP, a stack height of 61 m has been initially assumed, based on the data provided by Fluor and KNPC.

The CFP will provide fired equipment in MAB Units 111 (CDU), 112 (ARDS), 212 (ARDS) and 131 (Steam Generation) that will have dual fuel firing capability. In order to ensure compliance with the relevant K-EPA point source emission rate criteria, the fired equipment in these units will burn either fuel gas only or a mixture of fuel oil and fuel gas not to exceed more than 15% fuel oil.

9.2 Baseline Ambient Air Quality

The baseline air quality data provided in this section is based on the following information sources:

- KNPC HSE Ambient Air Monitoring Data for the period November 2005 to November 2006 for a selection of monitoring points at various refinery site boundaries (Section 5.2 of the Environmental Baseline Study for the KNPC CFP 2020, EBS Final Report, DNV No. 32317425 / Fluor Doc. No. P6000CFP.000.10R.02, Rev3, 5th June 2008)
- KISR measurements from baseline studies (Section 5.3 of the EBS report for the CFP Project)

As the air quality data have been presented, discussed and analysed in Section 5 (and associated appendices) of the CFP Project EBS Report, as referenced above, this section simply summarises the locations and ambient air quality data used for the purposes of the air modelling, from both sets of data available. Any exceedances, against the K-EPA / Ministry of Oil criteria, from these monitoring points are summarised at the end of this section.

The data for each monitoring point of interest will be combined with the predicted ADMS ground level concentrations at each point, to obtain an estimate of the resulting air quality at these sites after the CFP project is completed.

It should be noted that the existing background air quality does not currently meet the relevant K-EPA / MOO air quality criteria (e.g. for SO_2, TSP, etc).

9.2.1 Existing KNPC HSE Ambient Air Monitoring Data

As detailed in Section 5.2 of the CFP Project EBS report (DNV No. 32317425 / Fluor Doc. No. P6000CFP.000.10R.02), two sets of ambient air quality data were collected by KNPC HSE department at MAA, MAB and SHU refineries for monthly periods between November 2005 and November 2006. Monitoring took place for 24 hours a day, for a period of one month at ten different locations (see Table 5.1 from the CFP EBS Report). The locations of these monitoring points are indicated in Figures 9.1 to 9.3, for MAA, MAB and SHU refineries.

The KNPC HSE data monitoring locations are both onsite (locations A, B, E, G, I, J) and at the refinery boundary (C, D, F. H). The locations at the refinery boundary are required to meet K-EPA / MOO air quality criteria, hence the data provided for these four monitoring points have been averaged (for the total number of months for which data have been provided for each point) and converted to annual and 99.7%ile 1-hour average concentrations for the pollutants of interest, namely NO_2, SO_2, CO, H_2S and TSP (see Table 9.2). It was assumed that the monthly averages could be directly compared to the annual average criteria, whereas the daily average measurements for each location have been converted to equivalent 1-hour average concentrations using the factors (1.11 for this case) provided in the *Workbook of Atmospheric Dispersion Estimates, D. Bruce Turner, 2nd Edition, 1994.*

The resulting concentrations for these monitoring points have then been compared against the K-EPA / MOO criteria (Table 9.16) for each pollutant examined. The results from this comparison, along with the average concentrations at each monitoring point of interest, are presented and discussed in Section 9.2.3.

Figure 9.1: KNPC Ambient Air Monitoring Point Locations at MAA Refinery

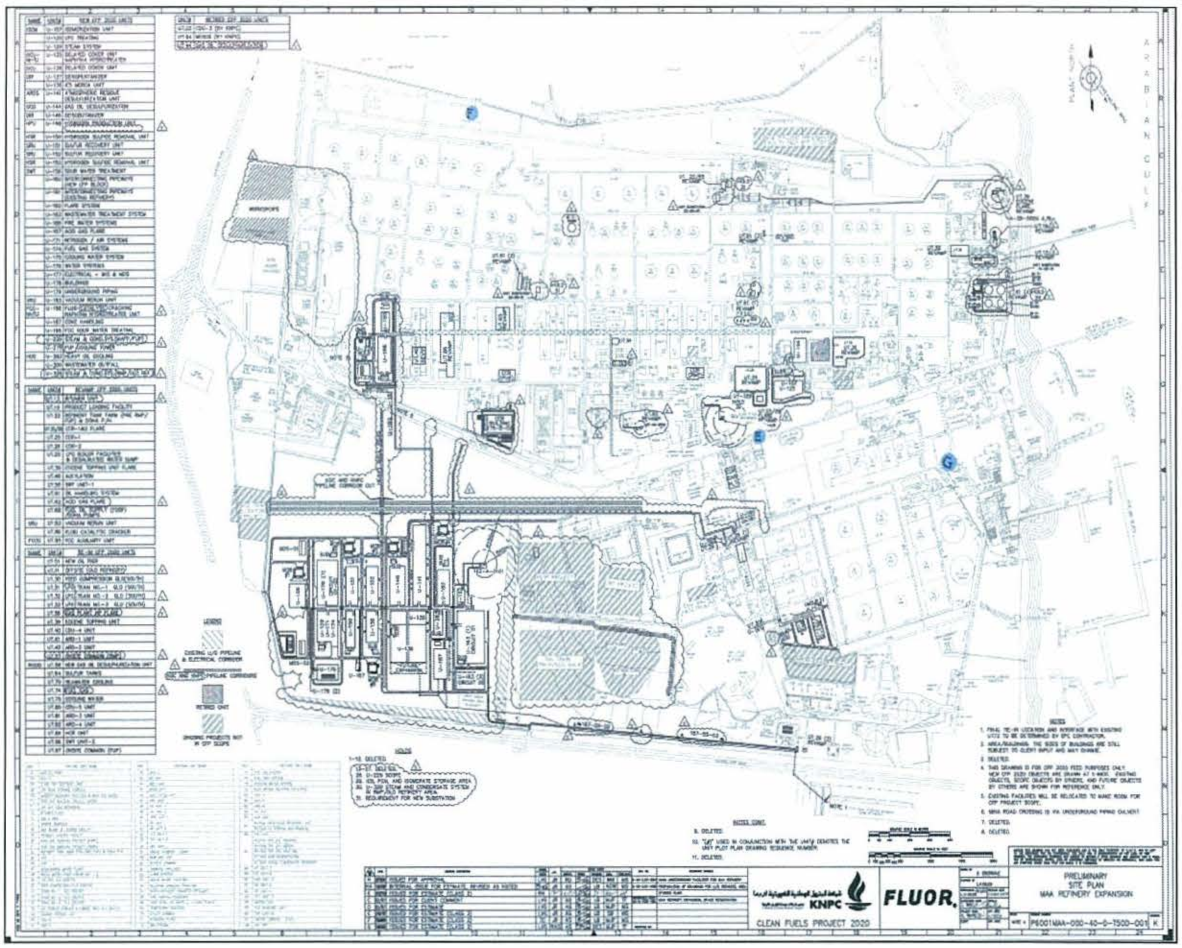


Figure 9.2: KNPC Ambient Air Monitoring Point Locations at MAB Refinery

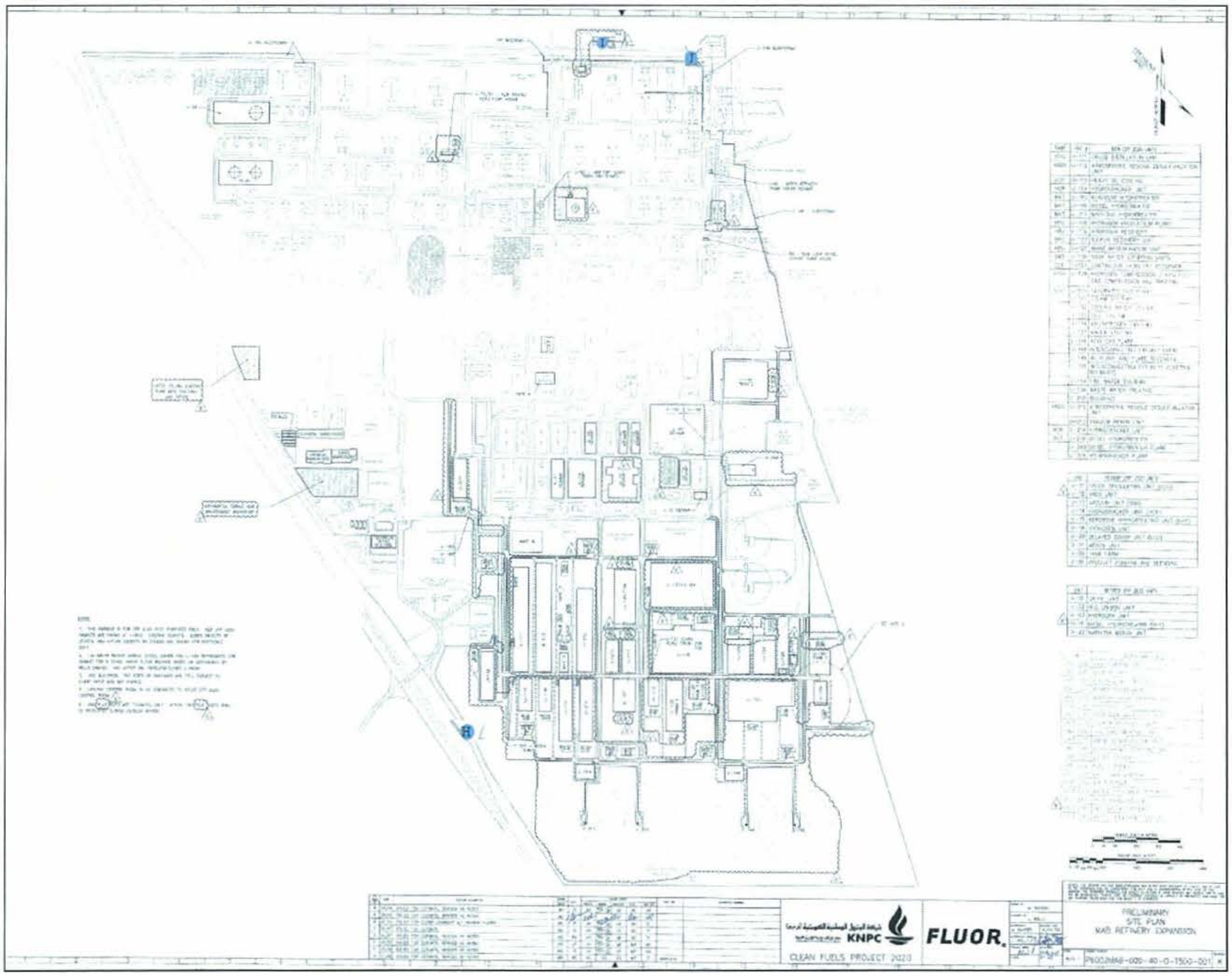
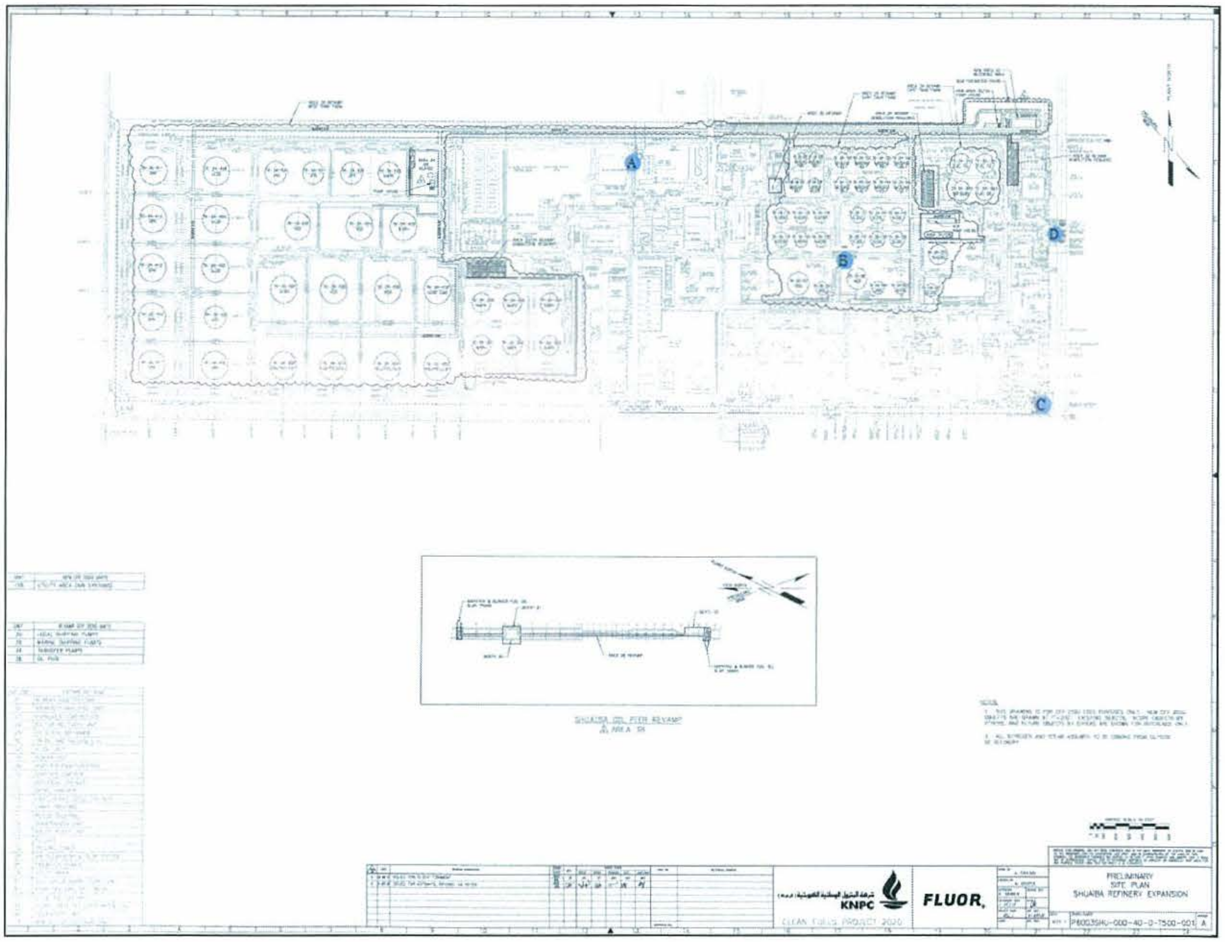


Figure 9.3: KNPC Ambient Air Monitoring Point Locations at SHU Refinery



9.2.2 Environmental Baseline Results 2007

As described in the Environmental Baseline Study (EBS) report (DNV No. 32317425 / Fluor Doc. No. P6000CFP.000.10R.02 - Chapter 5 and associated appendices), ambient air quality monitoring was also conducted at 45 monitoring sites (A1 to A45) within the CFP Project study area, extending to some distance outward from the site. Air sampling locations for the baseline survey covered a number of locations at each refinery (MAA, MAB and SHU), the adjacent coastal area, the nearby residential and industrial areas, as well as locations upwind and downwind of the refinery sites.

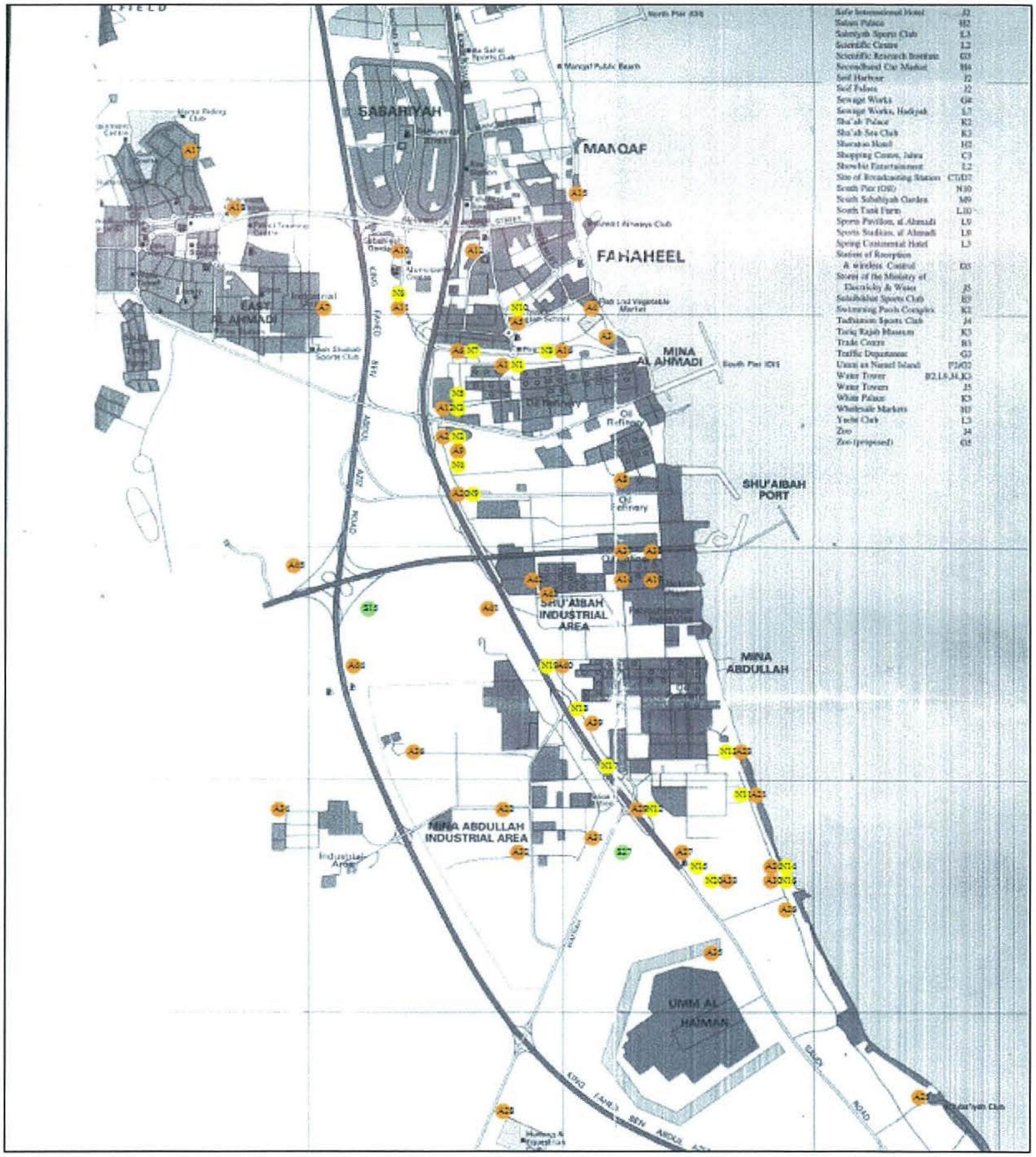
As Section 5.3 of the CFP Project EBS report covers the analysis and interpretation of the collected air monitoring data, this section simply summarises the selected data to be used for comparison against the applicable criteria. The locations of these monitoring points are indicated in Figure 9.4.

The data for all 45 monitoring points are used for the purposes of this study, and are compared to the applicable criteria in order to summarise any exceedances. The Diffusive Passive Sampler (DPS) data (for a sampling period of one month) for each point have been assumed to correspond to the annual average concentrations, whereas these monthly average measurements for each location have been converted to equivalent 1-hour average concentrations (99.7%ile) using the factors (1.25 for this case) provided in the *Workbook of Atmospheric Dispersion Estimates, D. Bruce Turner, 2nd Edition, 1994.* This approach was followed for NO_2, SO_2 and H_2S.

For the case of TSP, the results from the continuous air sampler were used. A daily averaging period was used when collecting the TSP samples at each location. The same method for converting these to results that can be compared against applicable, hourly-averaged, criteria has been used as for the existing KNPC HSE ambient air quality data (see Section 9.2.1 of this report). It is noted here that the annual average concentration value used for TSP is the actual data collected by the continuous air sample, making the comparison slightly conservative. Monitoring for TSP was only conducted for locations inside the three refineries.

The resulting concentrations for these monitoring points have been compared against the K-EPA / MOO criteria (Table 9.16) for each pollutant examined. The results from this comparison, along with the average concentrations at each monitoring point of interest, are presented in Section 9.2.3.

Figure 9.4: Ambient Air Quality Monitoring Point Locations (orange)



9.2.3 Ambient Air Quality Data against Criteria

This section summarises the results of the ambient air quality data, also highlighting any exceedances against the applicable criteria from K-EPA / MOO.

Firstly, the ambient air quality concentrations of interest, i.e. annual (long term) and 99.7%ile 1-hour (short term) average, for each monitoring point location are presented, followed by identification of areas of exceedance of criteria for any of the pollutants of interest.

These baseline concentrations of interest for each pollutant will later be combined with the ADMS modelling results at these particular monitoring point locations, in order to provide an indication of the air quality after the CFP project has been completed.

Table 9.2 summarises the baseline concentrations of interest for each pollutant at the monitoring points locations, whereas Table 9.3 indicates exceedances against the various pollutant criteria outlined in Table 9.16, by evaluating the ratio of the concentration at each monitoring point against the relevant criterion (exceedances highlighted in red, with the locations of the monitoring points indicated in Figures 9.1 to 9.4).

Table 9.2: Concentrations of pollutants at KNPC HSE & KISR Monitoring Points

Averaging Period	Annual					99.7%ile 1-hour Average				
	Pollutant									
Monitoring Location	NO2 µg/m³	SO2 µg/m³	H2S µg/m³	CO* µg/m³	TSP µg/m³	NO2 µg/m³	SO2 µg/m³	H2S µg/m³	CO µg/m³	TSP µg/m³
A1	20	32.5	6	-	570	25.0	40.6	7.5	N/A	632.7
A2	13	38	5	-	280	16.3	47.5	6.3	N/A	310.8
A3	13	18	5.8	-	180	16.3	22.5	7.3	N/A	199.8
A4	6.5	25.5	4.8	-	N/A	8.1	31.9	6	N/A	N/A
A5	15.5	19	5.7	-	N/A	19.4	23.8	7.1	N/A	N/A
A6	21.2	32.5	5.7	-	290	26.5	40.6	7.1	N/A	321.9
A7	11.5	30	5.5	-	N/A	14.4	37.5	6.9	N/A	N/A
A8	15.1	98	8.4	-	215	18.9	122.5	10.5	N/A	238.7
A9	14.5	40	8	-	175	18.125	50	10	N/A	194.3
A10	16.5	21	4.4	-	N/A	20.6	26.3	5.5	N/A	N/A
A11	14	23	5.2	-	N/A	17.5	28.8	6.5	N/A	N/A
A12	19.5	22	5.8	-	N/A	24.4	27.5	7.3	N/A	N/A
A13	13	40	4.3	-	195	16.3	50.0	5.4	N/A	216.5
A14	24.5	95	9.8	-	1010	30.6	118.8	12.3	N/A	1121.1
A15	15.5	13	5.9	-	N/A	19.4	16.3	7.4	N/A	N/A
A16	14.8	23	6.9	-	390	18.5	28.8	8.6	N/A	432.9
A17	10.1	24	4.3	-	N/A	12.6	30.0	5.4	N/A	N/A
A18	8.5	21	5.7	-	N/A	10.6	26.3	7.1	N/A	N/A
A19	15.5	119	8.1	-	190	19.4	148.8	10.1	N/A	210.9
A20	15.8	40	6.9	-	165	19.8	50.0	8.6	N/A	183.2
A21	19	85	7.4	-	720	23.8	106.3	9.3	N/A	799.2
A22	10.5	32.5	6.1	-	N/A	13.1	40.6	7.6	N/A	N/A
A23	20	85	10.7	-	430	25.0	106.3	13.4	N/A	477.3
A24	20	82	6.9	-	330	25.0	102.5	8.6	N/A	366.3
A25	9.8	30	5.8	-	N/A	12.3	37.5	7.3	N/A	N/A

Averaging Period	Annual					99.7%ile 1-hour Average				
	Pollutant									
Monitoring Location	NO2 µg/m³	SO2 µg/m³	H2S µg/m³	CO* µg/m³	TSP µg/m³	NO2 µg/m³	SO2 µg/m³	H2S µg/m³	CO µg/m³	TSP µg/m³
A26	11.5	43	7.4	-	N/A	14.4	53.8	9.3	N/A	N/A
A27	15	32.5	6.8	-	1103	18.8	40.6	8.5	N/A	1224.3
A28	10.2	23	0	-	N/A	12.8	28.8	0.0	N/A	N/A
A29	14.2	40	6.3	-	286	17.8	50.0	7.9	N/A	317.5
A30	16.5	68	6.5	-	460	20.6	85.0	8.1	N/A	510.6
A31	15	36	6.9	-	N/A	18.8	45.0	8.6	N/A	N/A
A32	10.5	32	7.2	-	N/A	13.1	40.0	9.0	N/A	N/A
A33	12	42.1	7.9	-	215	15.0	52.6	9.9	N/A	238.7
A34	5.8	10	14.5	-	N/A	7.3	12.5	18.1	N/A	N/A
A35	10.5	29	8.7	-	N/A	13.1	36.3	10.9	N/A	N/A
A36	10	35	6.7	-	N/A	12.5	43.8	8.4	N/A	N/A
A37	19	95	9.9	-	700	23.8	118.8	12.4	N/A	777.0
A38	16	110	9.6	-	205	20.0	137.5	12.0	N/A	227.6
A39	17	42.1	7.3	-	720	21.3	52.6	9.1	N/A	799.2
A40	15.2	16	5.7	-	605	19.0	20.0	7.1	N/A	671.6
A41	16	39	6.7	-	N/A	20.0	48.8	8.4	N/A	N/A
A42	10	36.5	6.6	-	995	12.5	45.6	8.3	N/A	1104.5
A43	13.5	45	6.1	-	220	16.9	56.3	7.6	N/A	244.2
A44	12	37	7.6	-	N/A	15.0	46.3	9.5	N/A	N/A
A45	16	36.5	7.5	-	N/A	20.0	45.6	9.4	N/A	N/A
KNPC C	156.6	31.0	16.0	-	1046.3	287.7	263.2	132.8	5825.5	3556.4
KNPC D	45.2	48.3	24.7	-	316.8	74.3	127.4	57.3	N/A	1386.3
KNPC F	69.0	21.2	5.4	-	526.4	184.0	183.3	29.5	2944.1	2024.2
KNPC H	53.1	29.9	3.7	-	201.5	92.7	86.2	13.0	N/A	589.5

* Long term (i.e. annual) concentrations are not applicable for Carbon Monoxide.

Table 9.3: Exceedances of Criteria for Ambient Air Quality

Averaging Period	Annual					99.7%ile 1-hour Average					99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)										Ratio against Industrial Criteria
Monitoring Location	NO2	SO2	H2S	CO*	TSP	NO2	SO2	H2S	CO	TSP	SO2
A1	0.30	0.41	0.75	-	7.60	0.11	0.09	0.19	N/A	1.99	0.05
A2	0.19	0.48	0.63	-	3.73	0.07	0.11	0.16	N/A	0.98	0.06
A3	0.19	0.23	0.73	-	2.40	0.07	0.05	0.18	N/A	0.63	0.03
A4	0.10	0.32	0.60	-	N/A	0.04	0.07	0.15	N/A	N/A	0.04
A5	0.23	0.24	0.71	-	N/A	0.09	0.05	0.18	N/A	N/A	0.03
A6	0.32	0.41	0.71	-	3.87	0.12	0.09	0.18	N/A	1.01	0.05
A7	0.17	0.38	0.69	-	N/A	0.06	0.08	0.17	N/A	N/A	0.05
A8	0.23	1.23	1.05	-	2.87	0.08	0.28	0.26	N/A	0.75	0.16
A9	0.22	0.50	1.00	-	2.33	0.08	0.11	0.25	N/A	0.61	0.06
A10	0.25	0.26	0.55	-	N/A	0.09	0.06	0.14	N/A	N/A	0.03
A11	0.21	0.29	0.65	-	N/A	0.08	0.06	0.16	N/A	N/A	0.04

Averaging Period	Annual					99.7%ile 1-hour Average					99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)										Ratio against Industrial Criteria
Monitoring Location	**NO2**	**SO2**	**H2S**	**CO***	**TSP**	**NO2**	**SO2**	**H2S**	**CO**	**TSP**	**SO2**
A12	0.29	0.28	0.73	-	N/A	0.11	0.06	0.18	N/A	N/A	0.04
A13	0.19	0.50	0.54	-	2.60	0.07	0.11	0.13	N/A	0.68	0.06
A14	0.37	1.19	1.23	-	13.47	0.14	0.27	0.31	N/A	3.53	0.15
A15	0.23	0.16	0.74	-	N/A	0.09	0.04	0.18	N/A	N/A	0.02
A16	0.22	0.29	0.86	-	5.20	0.08	0.06	0.22	N/A	1.36	0.04
A17	0.15	0.30	0.54	-	N/A	0.06	0.07	0.13	N/A	N/A	0.04
A18	0.13	0.26	0.71	-	N/A	0.05	0.06	0.18	N/A	N/A	0.03
A19	0.23	1.48	1.01	-	2.53	0.09	0.34	0.25	N/A	0.66	0.19
A20	0.24	0.50	0.86	-	2.20	0.09	0.11	0.22	N/A	0.58	0.06
A21	0.28	1.06	0.93	-	9.60	0.11	0.24	0.23	N/A	2.52	0.14
A22	0.16	0.41	0.76	-	N/A	0.06	0.09	0.19	N/A	N/A	0.05
A23	0.30	1.06	1.34	-	5.73	0.11	0.24	0.33	N/A	1.50	0.14
A24	0.30	1.03	0.86	-	4.40	0.11	0.23	0.22	N/A	1.15	0.13
A25	0.15	0.38	0.73	-	N/A	0.05	0.08	0.18	N/A	N/A	0.05
A26	0.17	0.54	0.93	-	N/A	0.06	0.12	0.23	N/A	N/A	0.07
A27	0.22	0.41	0.85	-	14.71	0.08	0.09	0.21	N/A	3.86	0.05
A28	0.15	0.29	0.00	-	N/A	0.06	0.06	0.00	N/A	N/A	0.04
A29	0.21	0.50	0.79	-	3.81	0.08	0.11	0.20	N/A	1.00	0.06
A30	0.25	0.85	0.81	-	6.13	0.09	0.19	0.20	N/A	1.61	0.11
A31	0.22	0.45	0.86	-	N/A	0.08	0.10	0.22	N/A	N/A	0.06
A32	0.16	0.40	0.90	-	N/A	0.06	0.09	0.23	N/A	N/A	0.05
A33	0.18	0.53	0.99	-	2.87	0.07	0.12	0.25	N/A	0.75	0.07
A34	0.09	0.13	1.81	-	N/A	0.03	0.03	0.45	N/A	N/A	0.02
A35	0.16	0.36	1.09	-	N/A	0.06	0.08	0.27	N/A	N/A	0.05
A36	0.15	0.44	0.84	-	N/A	0.06	0.10	0.21	N/A	N/A	0.06
A37	0.28	1.19	1.24	-	9.33	0.11	0.27	0.31	N/A	2.45	0.15
A38	0.24	1.38	1.20	-	2.73	0.09	0.31	0.30	N/A	0.72	0.18
A39	0.25	0.53	0.91	-	9.60	0.09	0.12	0.23	N/A	2.52	0.07
A40	0.23	0.20	0.71	-	8.07	0.08	0.05	0.18	N/A	2.12	0.03
A41	0.24	0.49	0.84	-	N/A	0.09	0.11	0.21	N/A	N/A	0.06
A42	0.15	0.46	0.83	-	13.27	0.06	0.10	0.21	N/A	3.48	0.06
A43	0.20	0.56	0.76	-	2.93	0.08	0.13	0.19	N/A	0.77	0.07
A44	0.18	0.46	0.95	-	N/A	0.07	0.10	0.24	N/A	N/A	0.06
A45	0.24	0.46	0.94	-	N/A	0.09	0.10	0.23	N/A	N/A	0.06
KNPC C	2.34	0.39	2.00	-	13.95	1.28	0.59	3.32	0.17	11.20	0.34
KNPC D	0.67	0.60	3.09	-	4.22	0.33	0.29	1.43	N/A	4.37	0.16
KNPC F	1.03	0.26	0.67	-	7.02	0.82	0.41	0.74	0.09	6.38	0.23
KNPC H	0.79	0.37	0.46	-	2.69	0.41	0.19	0.32	N/A	1.86	0.11

Note: The red highlighted cells indicate exceedance against K-EPA / MOO criteria.
* Long term (i.e. annual) concentrations are not applicable for CO.

9.3 Process Releases During Operation & Their Control

9.3.1 Point Source Emissions

Point source emissions generated by the CFP as by-products of combustion, will include NO_x, SO_2, CO, H_2S, suspended particulate matter (SPM), and unburned hydrocarbons (UHC), plus significant volumes of CO_2 (a greenhouse gas). In addition to the new point sources, several units from the three refineries (most of them located at SHU) will be decommissioned as part of the project. The removal of these emissions will help to improve the air quality in the area.

A summary list of air emission point sources is provided in Table 9.4 for the new sources installed as part of the CFP, whereas Table 9.5 summarises the sources that are to be decommissioned. Note these lists only include new (or revamped) and decommissioned sources that result in air pollutant emissions. Flare emission sources are not included in the new CFP sources summary table, as these will only be used intermittently (i.e. during emergencies which are discussed in Section 9.3.4).

Table 9.4: List of CFP New Fired Equipment air emission sources

Refinery	Source Name / Description	No. of sources	No. of stacks
MAA	Unit 135 DCU-NHTU	1	1
	Unit 136 DCU*	2	1
	Unit 183 VRU	1	1
	Unit 137 DIP	1	1
	Unit 186 FCC-NHTU HDS	2	2
	Unit 141 ARDS	2	2
	Unit 148 HPU	1	1
	Unit 129 Steam Boilers	3	3
	Unit 151 MAA - SRUs	1	1
	Unit 152 MAA - SRUs	1	1
	Unit 187 - Coke Handling	19	19
	Unit 25/26 NHT	2	2
	Unit 107 Isomerization	2	2
	Unit 144 – GOD	1	1
MAB	Unit 123 MAB - SRUs	3	3
	Unit 213	1	1
	Unit 117 NHT	1	1
	Unit 111 CDU*	2	1
	Unit 118 NHT TB / H2 RF	2	2
	Unit 115 KHT	1	1
	Unit 116 DHT	1	1
	Unit 112 ARDS	3	3
	Unit 212 ARDS	2	2
	Unit 114 HC	3	3
	Unit 127 CCR*	4	1
	Unit 127 CCR Stabilizer	1	1
	Unit 156 WWT	1	1
	Unit 11 CDU	1	1
	Unit 131 Steam Boilers	6	6

Refinery	Source Name / Description	No. of sources	No. of stacks
	Unit 214 Hydrocracker*	3	1
	Unit 216- DHT	1	1
	Unit 118 – H2 Plant	1	1

* For Unit 136 (2 heaters), Unit 111 (2 heaters), Unit 127 (4 reactor feed furnace), Unit 214 (3 HC heater),the emissions are combined.

(List does not include diesel engine drivers for emergency generators and firewater pumps which are used only intermittently)

Table 9.5: List of CFP Air Emission Sources for Planned Decommissioned Units

Refinery	Source Name / Description	No. of sources	No. of stacks
SHU	Unit 02 - Hydrogen manufacturing	1	4
	Unit 06 – Crude & Vacuum	1	7
	Unit 07 - Hot Oil	1	6
	Unit 08 - Isomax	1	2
	Unit 09 - Naphtha Fractionation	1	1
	Unit 11 - Kero Unifiner	1	6
	Unit 12 - Diesel Unifiner	1	4
	Unit 13 - Heavy Diesel Unifiner	1	2
	Unit 63 - Hot Oil Vacuum	1	1
	Unit 68 - Isocracker	1	4
	Unit 62 - Hydrogen manufacturing	1	2
	Unit 20 - Boilers	1	4
	Unit 05 - Catalytic Reformer	1	3
	Unit 10 - Naphtha Unifiner	1	2
	Unit 04 and Unit 74 SRUs[1]	2	2
MAB	Unit 01-Crude	1	9
	Unit 02-RCD Unibon	1	3
	Unit 03-Hydrogen Plant	1	1
MAA	Unit 99 TGTU[2]	1	1
	ESP on Unit 86[3]	1	1
	Unit 03-CDU # 3	1	1

1. Tail gas from these units (which are not decommissioned) is routed to TGTU 75 before discharge to atmosphere as a common stream after treatment.
2. Unit 99 is not a "decommissioned" unit, but a new pollution control unit (SCOT Unit) that will be commissioned to improve emissions from the existing MAA SRU. As such, it will be an improvement to the air quality, and consequently has been grouped together with the "Decommissioned" Units.
3. Similarly, Unit 86 ESP is a new pollution control facility which will improve particulate emissions from the existing plant, and as such has also been grouped with the "Decommissioned" Units.

Control of point source emissions such as these can be accomplished by various methods including pre-combustion techniques, combustion techniques and post-combustion techniques. Pre-combustion control techniques entail the careful selection and treatment of fuel which, based on the type and composition of crude oil from which it is derived, may contain significant amounts of sulphur / sulphur compounds and / or nitrogen: these in turn give rise to SO_2 and NO_x emissions during combustion.

The CFP will also incorporate combustion techniques to minimise the generation of air emissions, including management practices to ensure efficient operation of equipment as well as engineered emission control systems. Process heaters, furnaces and boilers will be equipped with low NOx burners ('LNBs').

In keeping with KNPC's commitment to environmental stewardship, a substantial financial investment is being made in providing reliable and highly efficient facilities to recover sulphur from process streams while ensuring SO_2 emissions are minimized. As part of the CFP project three new SRU units are provided, two at MAA (Units 151 and 152 - two trains) and one at the MAB (Unit 123 – three trains) refinery. The SRU unit at SHU Refinery is to be decommissioned (Unit 74 – two trains).

The Sulphur Recovery Unit/Tail Gas Treating Units will be comprised of four parallel plants, each comprising:

- One Claus section
- One SCOT section
- One degassing section
- One incineration section

The SCOT tail gas (or Claus tail gas in case the SCOT section is bypassed) and the vent gas from the sulphur storage contain residual H_2S and other sulphur compounds which are thermally incinerated to convert the H_2S and sulphur compounds into SO_2. NOx formation from the burner is reduced by limiting the primary air flow rate to 80% of the amount required for stoichiometric combustion of the fuel gas. Vent gas from the incinerator stack is expected to contain < 10ppmv H_2S and < 250 ppmv SO_2 on a dry and zero excess oxygen basis.

Units 151 and 152 at MAA are identical, and each consists of a single train. Normally, both units will be in operation. At MAB, Unit 123 consists of three identical trains, which will all normally be in operation.

Suspended particulate matter (SPM) emissions are primarily a result of construction activities (see Chapter 8). The Electrostatic Precipitator (ESP) currently being installed on Unit 86 (FCCU) at MAA has been accounted for the purposes of this study.

9.3.2 Fugitive Emissions

Fugitive emissions generated by the CFP during its operations will potentially arise from valves, flanges, pumps as well as from pressure-relief valves during abnormal and/or emergency situations. Fugitive emissions at the CFP may include suspended particulate matter (SPM), hydrogen sulphide (H_2S) and VOCs, as follows:

Fugitive SPM:

The new Coke Handling Unit at MAA (Unit 187) will incorporate covered conveyor systems to minimize the potential generation of wind blown particulate matter as well as particulate control systems at each of the nineteen transfer towers.

Fugitive H_2S:

- Potentially released from both ISBL and OSBL areas of the CFP where sour-gas or sour liquids are handled, processed or stored.
- Low-leak seals will be provided for equipment components in sour-gas or sour-liquid service as appropriate, and will be monitored on a regular basis as part of the CFP's overall Leak Detection and Repair (LDAR) programme.

- Ambient H_2S monitors will be sited in those areas with the greatest potential for H_2S fugitive emissions; should H_2S concentrations exceed the established alert threshold level, an alarm in the local control room will notify operators of a leak and need to immediately initiate appropriate response and repair actions.

Fugitive VOCs:
- Potentially released from both ISBL and OSBL areas of the CFP where equipment is in hydrocarbon service, including process and treatment units and storage tanks. VOC emissions will be minimized through efficient design, application of engineering controls and EMS procedures.
- Control techniques will include: relief valves routed to flare, open-ended valves equipped with cap, plug, blind flange or second valve, pumps incorporating double mechanical seals, reciprocating compressors designed with cylinder packing case venting to flare system, centrifugal compressors provided with dry gas seals and nitrogen buffer gas-venting to flare system, and closed process drains and effluent sumps.

Regarding the CFP's new Wastewater Treatment Unit (Unit 163 at MAA and Unit 156 at MAB), treatment systems in contact with hydrocarbons or odorous compounds will be enclosed where feasible. In addition:
- CFP Wastewater plant equipment components in VOC service including valves / pumps / flanges etc will be incorporated in the existing refineries' Leak Detection and Repair (LDAR) Programme, requiring the identification of affected components and regular inspections of those components. An equipment leak definition of 10,000 ppmv VOC will be used as a guideline;
- Monitoring frequency will be monthly on a rotation basis for the wastewater treatment facilities, storage tank areas and process units / work environment area. A protocol will be developed for responding and making repairs to leaking components.
- Liquid sample points will be designed to minimize hydrocarbon or product loss to the drainage system, and closed-loop sampling will be used wherever possible to minimize operator exposure and emissions during sample purging.

Storage tanks in VOC service will meet all applicable K-EPA / MOO air emissions criteria:
- Regulatory control requirements include: use of primary seals, secondary seals (external floating roof tanks) for various compounds subject to specified vapour pressure and storage tank design criteria;
- Pole wipers will be provided for floating roof tanks, and automatic bleeder vents (vacuum breaker vents) will be kept closed at all times except when the roof is being floated off or landed on the roof leg supports;
- All gauging and sampling devices will be kept vapour tight except when those activities are in progress.
- The CFP facilities will be incorporated within the existing MAA and MAB refineries EMS. The EMS will be updated to include a protocol and schedule for inspection of seals on floating roof storage tanks (VOC emissions from storage tanks are typically estimated using the latest version of U.S. EPA's TANKS programme, which is based upon AP-42 emission factors).

CFP will not modify or increase the number of loading arms currently in use at refinery port facilities. Therefore, VOC emissions resulting from transfer operations at the port have not been included in this analysis.

It is noted that the CFP will not implement any new HSE programmes. The new CFP facilities will be incorporated in into existing refineries programmes in order to ensure they are properly monitored, inspected and maintained to minimise potential environmental impacts.

9.3.3 Hazardous and Deleterious Air Pollutants

Kuwait is a signatory to the Montreal Protocol and its subsequent amendments for the protection of stratospheric ozone. As such, the CFP will seek to avoid the use of ozone-depleting substances (ODSs) such as chlorofluorocarbons (CFCs) and halons, wherever acceptable (i.e. environmentally-friendly) substitutes are available.

Preference will be given to chemicals which are regarded as acceptable substitutes to those chemicals that have the greatest deleterious impact on stratospheric ozone. Some acceptable substitutes for the most deleterious chemicals – e.g. HCFC-22 as a substitute for R-502 (already phased out of production) in industrial process refrigeration systems – are also scheduled for phase-out in 2020. Engineering design will take into account all ODSs that are to be phased out during the CFP's operating life.

No asbestos products will be used in either the construction or operation of the CFP, nor will chromium-based corrosion inhibitors be used for cooling water treatment.

9.3.4 Emergency Emissions

Flares

The Flare system for CFP serves as the final line of protection against catastrophic failure resulting from overpressure of equipment and interconnecting piping. Its' purpose is to provide the means for the safe relief and combustion of potentially explosive and/or toxic fluids. These fluids, which are present as feeds, products, or intermediate streams within the refinery processes, must be flared under *unplanned* upset conditions. These streams will be collected through a closed system and directed to the flares after phase separation via 'knock-out' (KO) drums.

Additionally, under typical refinery operation, gases may be vented or liquids blown down to the flare to maintain a required process operating pressure. It is also common practice to start-up or shutdown a process unit by temporarily venting hydrocarbon gases to the flare until the unit can be properly lined out (start-up) or de-pressured and purged (shutdown). However, for the CFP, refinery operations will implement suitable sequencing of unit start-ups and shutdowns to minimize simultaneous planned flaring from different process units.

A Flare Gas Recovery Unit (FGRU) will be installed in the future to permit the recovery of gases which would normally be flared, and then return them back to the processing units.

The CFP's Relief and Flare System will meet all KNPC design guidelines for smokeless flame operation, noise limits, radiation limits, and dispersion levels as well as the applicable K-EPA / MOO criteria. Flaring will be reduced by selecting relief valves and control valves designed to keep internal leaks to a minimum.

CFP will include both a hydrocarbon flare system and an Acid Gas Flare (AGF) System at each of MAA and MAB refineries. All new flares at the two refineries will be elevated.

In addition to the new CFP flare systems, some of the existing flare systems at MAA refinery will have tie-ins with relief valves in CFP process units, hence adding to the existing flare load. These reliefs have also been considered when assessing the air quality both within and beyond the fence-line of the refineries.

The flare systems considered in the scope of this study are summarised in Table 9.6. The scenarios considered are discussed in more detail in Section 9.4.

Key environmental emissions from the flares will constitute significant atmospheric emissions during emergency relief. However, emissions are expected to be minimal during normal refinery operations.

Table 9.6 – Flares Emission Modelling Scenarios

Refinery	Flare System / New or Existing	Description / Notes
MAA	Unit 167 Acid Gas – New	New acid gas flare system at MAA.
	Unit 162 Hydrocarbon – New	New hydrocarbon flare system at MAA.
	Unit 25/26 CCR 1 & 2 – Existing	Revamped flare system for catalytic cracking unit at MAA.
	Unit 39 Eocene – Existing	Revamped Eocene flare system at MAA.
	Unit 62 Acid Gas – Existing	Revamped acid gas flare system at MAA.
MAB	Unit 146 Acid Gas - New	New acid gas flare system at MAB.
	Unit 149 HP Hydrocarbon – New	New high pressure hydrocarbon flare system at MAB.
	Unit 149 LP Hydrocarbon – New	New low pressure hydrocarbon flare system at MAB.
	Unit 249 DHT – New	New flare system for diesel hydrotreater unit at MAB.
	Unit 314 HP HCR – New	New high pressure flare system for hydrocracker unit at MAB.
	Unit 314 LP HCR - New	New low pressure flare system for hydrocracker unit at MAB.

Sulphur Recovery and Handling System

In keeping with KNPC's commitment to environmental stewardship, a substantial financial investment is being made in providing reliable and highly efficient (99.9+%) facilities to recover sulphur from process streams while ensuring SO_2 emissions are minimized. As part of the CFP project three new SRU units are provided, two at MAA (Units 151 and 152 - two trains) and one at the MAB (Unit 123 – three trains) refinery. Additionally, the SRU unit (Unit 74 – two trains) at SHU Refinery will be decommissioned.

The SRU/TGTU design provides a very high degree of reliability. However, there are two emergency case scenarios for each of the units at MAA and MAB, both rare and of short duration which if were to occur, would result in significantly higher than normal emissions of SO_2 and/or H_2S:

1. SRU operating SCOT sections are bypassed (SRUs "Case 2")
2. SRU operating when SCOT sections are bypassed, and the incinerator is not operating (SRUs "Case 3")

Four (4) cases have been considered / modelled in total, as it has been assumed that emergency events will not occur simultaneously at the two refineries (MAA and MAB):

- For SRUs Case 2 at MAA, one of the two trains at MAA (Units 151 and 152) is modelled under emergency conditions.
- For SRU Case 2 at MAB, one of the three trains at MAB (Unit 123) is modelled assuming under emergency conditions.
- Similarly, for SRUs Case 3 at MAA, only one of the two trains at MAA (Units 151 and 152) is modelled under emergency conditions.
- For SRU Case 3 at MAB one of the three trains at MAB (Unit 123) is modelled under emergency conditions.

As mentioned above, this is to account for the fact that it is highly unlikely that more than one SCOT unit at either refinery will be bypassed at the same time.

The scenarios are outlined in Table 9.13. It is also noted here that it is unlikely that the incinerator will ever be out of service during its operational life.

These scenarios are not typical of normal refinery operations. However, they have been evaluated through an air dispersion modelling analysis as an emergency release case(s) for which the results are presented in Section 9.4.6.3.

9.3.5 Maintenance /Shutdown Scenarios

Two maintenance events (at the RMP and CFP block) are anticipated to occur once every four to five years at MAA, and expected to last for up to 30 days. This would result in higher than normal emissions of SO_2 from Unit 107 and Unit 137, as the fired heaters would only be operated on sour fuel gas, because sweet refinery fuel would not be available during the shutdown. During these maintenance events other units will also be shutdown, and this is incorporated in the air dispersion modelling. It is not expected that shutdowns of the CFP and RMP blocks will occur simultaneously.

Table 9.7 – Maintenance /Shutdown Emissions Modelling Scenarios

Maintenance Scenario	Refinery Unit	Status	Name
Maintenance 1 RMP Block Shutdown	MAA New	Running on sour fuel gas	Unit 107
	MAA New	Shutdown	Unit 144
	MAA Existing	Shutdown	KD Unit
	MAA Existing	Shutdown	ARDS 1
	MAA Existing	Shutdown	ARDS2
	MAA Existing	Shutdown	HP-1
	MAA Existing	Shutdown	HP-2
	MAA Existing	Shutdown	SR/TGT
Maintenance 2 CFP Block Shutdown	MAA New	Running on sour fuel gas	Unit 137
	MAA New	Shutdown	Unit 129
	MAA New	Shutdown	Unit 135
	MAA New	Shutdown	Unit 136
	MAA New	Shutdown	Unit 141
	MAA New	Shutdown	Unit 148
	MAA New	Shutdown	Unit 151
	MAA New	Shutdown	Unit 152
	MAA New	Shutdown	Unit 183

Table 9.7 outlines the two maintenance cases. Both cases are modelled with "Normal Emissions" and combined with the Decommissioned Units. The results are presented in Section 9.4.6.8.

9.4 Modelling

9.4.1 Atmospheric Dispersion Modelling

As part of identifying and assessing the major sources of emissions to air from the CFP Project, including both major continuous emission sources such as those from boilers, heaters, furnaces, flares and incinerators, and fugitive emissions (e.g. VOCs), DNV has subjected the most significant ones to air quality modelling and assessment, using the Atmospheric Dispersion Modelling Software / Version 4.1 ('ADMS 4'). The ADMS software was presented to K-EPA during the previous FEED Phase EIS. K-EPA has approved the ADMS software for conducting the study.

The dispersion model ADMS 4 is currently used in many countries worldwide, with users including:

- over 130 individual company licence holders in the UK
- regulatory authorities, including the UK's Health and Safety Executive (HSE)
- the Environment Agency in England and Wales and the Scottish Environmental Protection Agency (SEPA)
- the Environment and Heritage Service in Northern Ireland
- government organisations including the Food Standards Agency (UK)
- users in other European countries, Asia, Australia and the Middle East.

ADMS 4 can be used to assess the effect of emissions from a wide range of industrial / process types such as power plant, boilers, heaters, furnaces, flares and incinerators, and a number of industrial source types:

- Point source: e.g. emissions from a stack or vent;
- Area source: e.g. evaporative emissions from a tank;
- Volume source: e.g. fugitive emissions;
- Jet (directional releases): e.g. emissions from a ruptured pipe.

The maximum number of sources that can be modelled in ADMS 4 is 300, depending on the source type, and it is typically applied to major continuous emissions (e.g. NO_2, SO_2 etc). The model uses relevant input parameters such as local meteorological data, terrain, significant buildings and ground cover, in order to assess ground level concentrations of pollutants both on and off-site for the relevant averaging periods (e.g. 1 hour average, annual average etc) as specified by K-EPA air quality standards.

All the monitoring point locations discussed in Section 9.2 (KNPC C, D, F and H, A1 to A45) have been included as specific points of interest in the various ADMS models examined, in order to estimate the ground level concentrations after the completion of the CFP project.

9.4.2 Modelling Approach

There are two alternative approaches in examining the effects of the CFP and decommissioning of SHU on the overall air quality in the area:

(1) Model all KNPC air pollutant emission sources that will exist in the future, post-CFP (i.e. model new/revamped CFP sources in addition to the existing refinery emission sources (but excluding any existing refinery sources that will be decommissioned as part of the CFP project).

(2) Model only the new CFP emission sources (i.e. new/revamped sources) plus additionally, negatively model the existing sources that will be decommissioned as part of the CFP project. This data can then be combined with the current baseline air quality from the monitoring data that KNPC HSE provided for the CFP EBS development.

Approach (2) has been followed to estimate the effects of the CFP on the overall quality, as it has the significant advantage that modelling results can be combined with the extensive EBS baseline air quality monitoring data available to provide adequate representation of the future ambient air quality (resulting from all sources, both KNPC and non-KNPC) in the surrounding environment post-CFP. This can then be compared against relevant K-EPA / MOO air criteria.

9.4.3 Modelling Scenarios & Source Data

Based on information available at this stage, the following scenarios have been modelled:

- The **"Base Case"** Scenario: This combines the negative environmental impact of the 'Normal' emissions from the new CFP Units/Sources at MAA and MAB refineries with the positive contribution to the environment as a result of decommissioning events at the 3 refineries. The decommissioning at each of the three refineries, with the vast majority of these located at the SHU Refinery, is treated as an improvement to air quality.
- The **"Maximum Emission"** Scenario: This combines the negative environmental impact of the 'Maximum" emissions from the new CFP Units/Sources at MAA and MAB refineries with the positive contribution to the environment as a result of decommissioning events at the 3 refineries. The decommissioning at each of the three refineries, with the vast majority of these located at the SHU Refinery, is treated as an improvement to air quality. Note that for some units, Normal and Maximum emissions are the same, but in general emissions are significantly less for the Normal scenario.
- **Emergency Flare** Scenarios – Various emergency flare scenarios have been considered, which are discussed in Section 9.3.4, and summarised in Table 9.11 and Table 9.12. The emergency flare scenario results for each flare are not combined with either the "Normal Emission" or the Decommissioned scenarios, as these pollutant emissions will be negligible in comparison to the flare emissions. With the exception of the Total Power Failure (TPF) case, each flare scenario is modelled individually. The TPF case is modelled assuming all

emergency flaring occurs simultaneously at both MAA and MAB refineries, for all relevant flares.

An exit velocity of 40 m/s has been assumed for the purposes of each flare scenario considered (consistent with applicable guidelines for flare modelling). Based on this assumption, an effective diameter for the flare point source was estimated for input to ADMS. Complete combustion of the flare destruction stream (with 20% excess air) has been assumed. Since the hot plume emission begins at the top of the flame, the height corresponding to the flame height / length has been estimated based on ADMS guidelines (i.e. the flame height / length is a function of the heat release rate and effective diameter, i.e. the flame diameter, and the density, heat capacity and temperature of ambient air). The flame height is then added to the flare stack height, resulting to the effective release height required as an input to ADMS.

- **Emergency SRU** Scenarios - The SRUs upset conditions considered are outlined below (see also Section 9.3.4):

  1. SRU operating while SCOT sections are bypassed (SRUs "Case 2")
  2. SRU operating while SCOT sections are bypassed, and the tail gas incinerator is not operating (SRUs "Case 3")

  These scenarios are combined with the **"Normal Emission"** Scenario. The emergency case results are not combined with the decommissioned scenario results, as the effect of them on the predicted concentrations will be minimal.

- **VOC Fugitive Emissions** from storage tanks in hydrocarbon service (see Section 9.4.6.7).

- Two **Maintenance Event scenarios** are considered as outlined below (see Section 9.4.6.8) and are modelled with "Normal Emissions" and combined with "Decommissioned Units" emissions.

  1. RMP Block shutdown resulting in Unit 107 (two fired heaters) receiving sour gas fuel. This would result in increased SO_2 emissions but the fired equipment in RMP block will not emit any SO_2 during this period, hence it will offset the emissions from Unit 107.
  2. CFP block shutdown resulting in Unit 137 (one fired heater) receiving sour gas fuel. This would result in increased SO_2 emissions but the fired equipment in CFP block will not emit any SO_2 during this period, hence it will offset the emissions from Unit 137.

The parameters NOx, SO_2, CO have been modelled for the Decommissioned, Normal and Maximum scenarios, as these are the key parameters of concern to K-EPA and the Kuwait Ministry of Oil. Additionally, Total Suspended Particles (TSP) have been modelled for the Decommissioned and Normal scenarios, with H_2S modelled only for the new CFP sources at MAA and MAB refineries (i.e. Normal and Maximum Emission Scenarios).

Buildings have not been taken into account during modelling, because the main building structures are at a significant distance from the stacks/chimneys, which are also significantly higher than the buildings. Consequently the effect of buildings upon dispersion is considered minimal.

The source data are summarised in Table 9.8 to Table 9.14, for the Normal, Maximum and Decommissioned emission scenarios, Flare and SRUs emergency and upset scenarios and the two maintenance scenarios respectively.

Additionally Table 9.15 compares the emissions of different pollutants (NO_x and SO_2) for the new CFP sources for Normal operating conditions against the equivalent emissions decommissioned at Shuiaba. It is clear that overall atmospheric emissions of pollutants will decrease.

The storage tanks modelled for fugitive emissions are discussed in Sections 9.3.2 and 9.4.6.7, and summarised in Appendix I.

Figure 9.5 and Figure 9.6 illustrate the location of the ADMS point source input emission sources for the Decommissioned and New CFP-Sources of the Clean Fuels Project respectively. The red line in these figures represents the site boundary for all three (MAA, MAB, and SHU) refineries. Figure 9.7 illustrates the location of the flares considered for emergency flaring events.

Figure 9.5: Location of ADMS Input Point Sources for Decommissioned Units

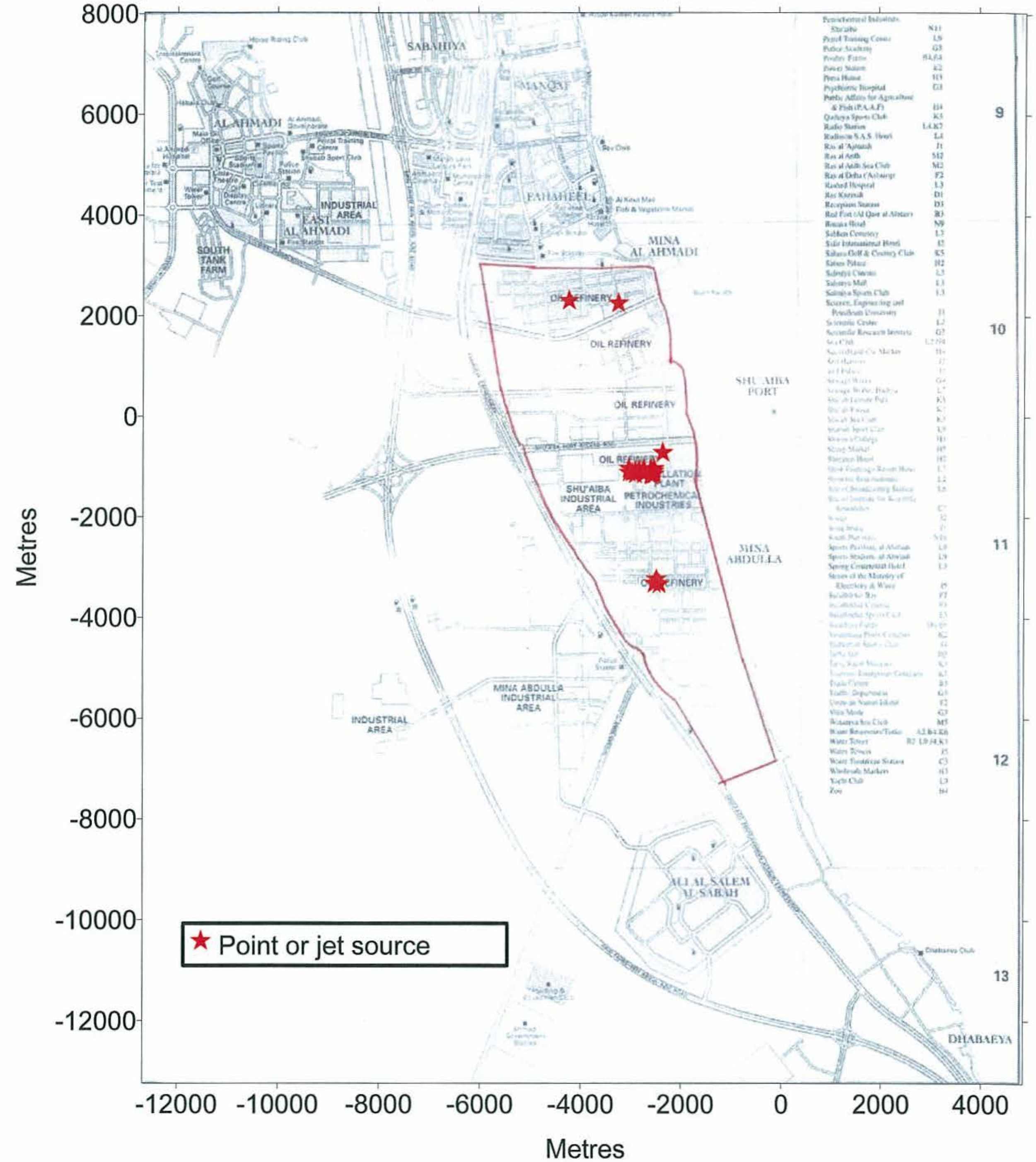


Figure 9.6: Location of ADMS Input Point Sources for New CFP Units

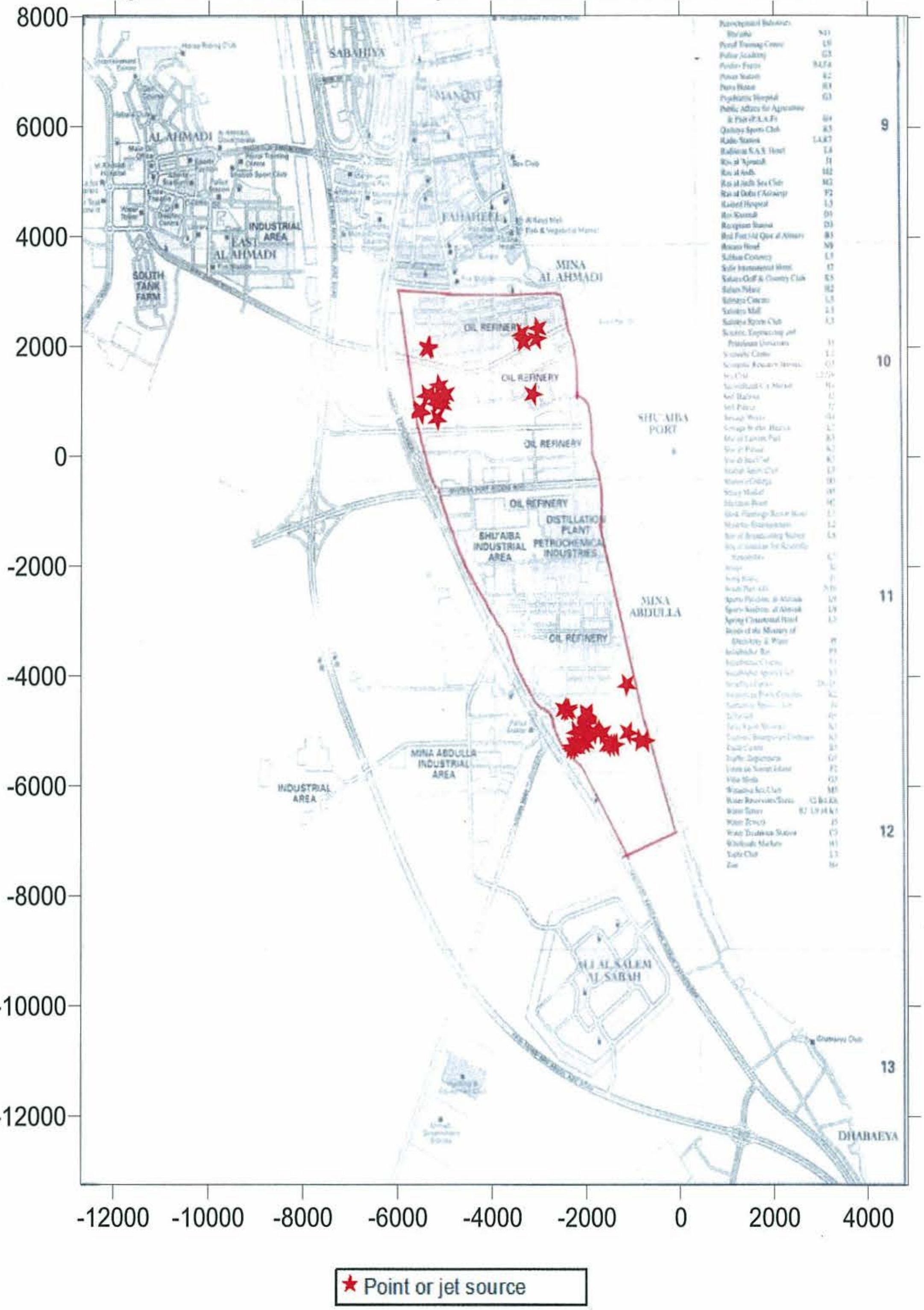


Figure 9.7: Location of ADMS Input Point Sources for Flare Systems Considered

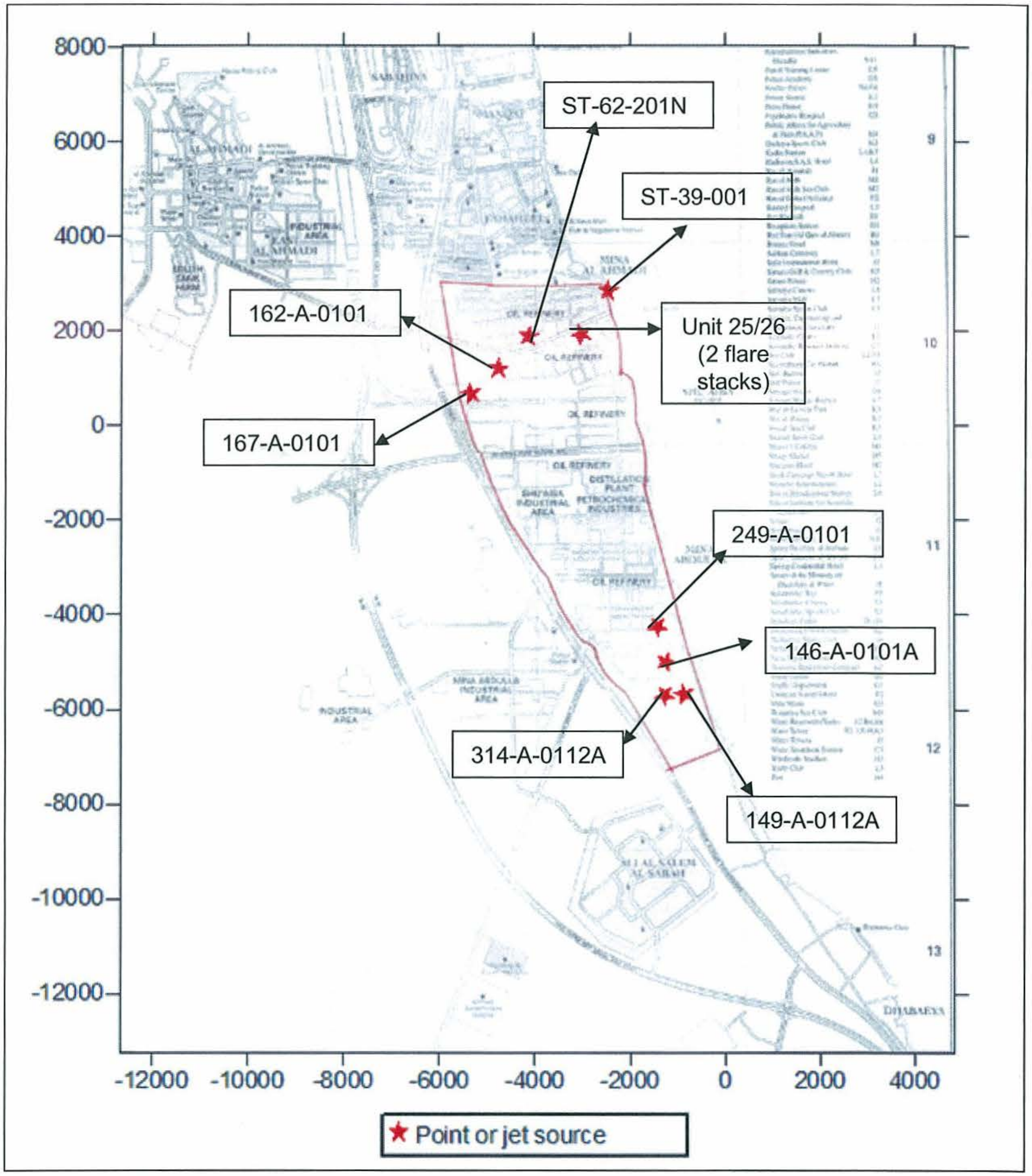


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Table 9.8: Point Emission Sources and Emission Levels (Normal Case for New Sources)

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
MAA	Unit 135 DCU-NHTU	135-F-0101	0.06	0.01	0.11	-	-	61	7.6	321	0.5
	Unit 136 DCU[2]	136-F-0201A/B	4.51	0.28	2.71	-	-	61	4.7	150	3.3
	Unit 137 DIP Reboiler Heater	137-F-0101	2.65	0.17	1.59	-	-	61	6.8	182	2.3
	Unit 141 ARDS	141-F-0201	0.94	0.13	0.57	-	-	65	7.4	150	1.5
		141-F-0401	1.11	0.17	0.67	-	-	65	7.4	150	1.5
	Unit 148 HPU	148-F-0301	3.51	0.03	4.68	-	-	61	10.3	154	2.8
	Unit 129 Steam Boilers[1]	129-F-0201A	5.40	0.30	3.24	-	-	65	5.3	293	4.1
		129-F-0201B	5.40	0.30	3.24	-	-	65	5.3	293	4.1
		129-F-0201C	5.40	0.30	3.24	-	-	65	5.3	293	4.1
	Unit 151/152 TGTU	151-F-0132	0.76	0.67	0.03	0.06	-	61	14*	270	1.4
	Unit 151/152 TGTU	152-F-0132	0.76	0.67	0.03	0.06	-	61	14*	270	1.4
	Unit 183 VRU	183-F-0101	2.53	0.16	1.52	-	-	61	5.7	204	2.1
	Unit 186 FCC-NHTU HDS	186-F-0201	0.10	0.02	0.17	-	-	65	6.3	363	1.0
		186-F-0202	0.13	0.02	0.22	-	-	65	6.3	372	1.1
	Unit 25/26 NHT Charge Heater (revamp existing)[5]	H25-101	0.18	0.03	0.31	-	-	31.6	3.2	316	1.3
		H26-101	0.18	0.03	0.31	-	-	31.6	3.2	316	1.3
	Unit 107 Isomerization	107-F-0101	0.37	0.06	0.61	-	-	61	4.2	293	1.8
		107-F-0102	4.59	0.29	2.76	-	-	61	4.3	188	3.5
	Unit 144 GOD	144-F-0101	0.24	0.04	0.40	-	-	61	7.0	329	1.2
MAB	Unit 111 Crude Distillation - 2 Heaters[2]	111-F-0101A/B	6.87	0.43	4.12	-	-	61	4.4	177	4.5
	Unit 112 ARDS Reactor Feed Furnace Train 1	112-F-0101	1.19	0.16	0.71	-	-	65	7.6	150	1.5
	Unit 112 ARDS Reactor Feed Furnace Train 2	112-F-0201	1.19	0.16	0.71	-	-	65	7.6	150	1.5
	Unit 112 ARDS Atmospheric Fractionator Feed Furnace	112-F-0401	2.28	0.31	1.39	-	-	65	7.4	150	2.2
	Unit 212 ARDS Reactor	212-F-0101	1.19	0.16	0.71	-	-	65	7.6	150	1.5

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
	Feed Furnace										
	Unit 212 ARDS Atmospheric Fractionator Feed Furnace	212-F-0401	1.14	0.17	0.69	-	-	65	7.3	150	1.6
	Unit 114 Hydrocracker 1st Stage Gas Heater	114-F-0101	0.27	0.05	0.45	-	-	61	5.1	159	1.6
	Unit 114 Hydrocracker 2nd Stage Gas Heater	114-F-0102	0.37	0.06	0.61	-	-	61	5.2	159	1.7
	Unit 114 Hydrocracker Product Fractionator Feed Furnace	114-F-0103	4.47	0.28	2.68	-	-	61	10.1	159	4.0
	Unit 115 KHT Reactor Feed Furnace	115-F-0101	0.09	0.02	0.14	-	-	61	7.6	413	1.3
	Unit 116 DHT Reactor Feed Furnace	116-F-0101	0.49	0.09	0.83	-	-	61	10	216	1.8
	Unit 117 NHT Reactor Feed Furnace	117-F-0101	0.03	0.01	0.05	-	-	61	7.6	397	0.5
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 1)	118-F-0101	10.09	1.19	11.41	-	-	61	9.7	155	5.0
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 2)	118-F-0201	10.09	1.19	11.41	-	-	61	9.7	155	5.0
	Unit 123 SRU-TGTU Tail Gas Incinerator	123-F-0132	1.67	1.47	0.14	0.25	-	61	15*	270	1.7
	Unit 123 SRU-TGTU Tail Gas Incinerator	123-F-0232	1.67	1.47	0.14	0.25	-	61	15*	270	1.7
	Unit 123 SRU-TGTU Tail Gas Incinerator[6]	123-F-0332	1.67	1.47	0.14	0.25	-	61	15*	270	1.7
	Unit 127 CCR Reactor Feed Furnace [2]	127-F-0101, 0102, 0103, 0104	1.14	0.20	1.92	-	-	61	10.8	193	2.6
	Unit 127 CCR Stabilizer Reboiler	127-F-0105	0.10	0.02	0.16	-	-	61	10.5	283	0.9
	Unit 213 VRU Vacuum	213-F-0101	1.97	0.12	1.18	-	-	61	5.7	204	2.2

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
	Charge Heater										
	Unit 11 CDU Fired Heater (existing) [4,5]	H-11-101	4.86	0.30	2.92	-	-	70	13.0	185	2.5
	Unit 131 Steam System Utility Boiler	131-F-0201A	2.80	0.18	1.68	-	-	65	5.3	175	2.2
		131-F-0201B	2.80	0.18	1.68	-	-	65	5.3	175	2.2
		131-F-0201C	2.80	0.18	1.68	-	-	65	5.3	175	2.2
		131-F-0201D	2.80	0.18	1.68	-	-	65	5.3	175	2.2
		131-F-0201E	2.80	0.18	1.68	-	-	65	5.3	175	2.2
		131-F-0201F	2.80	0.18	1.68	-	-	65	5.3	175	2.2
	Unit 156 WWT Oily Sludge Incinerator	156-A-0209-F01	0.06	0.01	0.09	-	-	20	6.8	950	0.9
	Unit 214 Hydrocracker - 3 Heaters Combined [2]	214-F-0101/0102/0103	4.68	0.36	3.44	-	-	61	4.3	136	3.7
	Unit 216 DHT Reactor Feed Furnace	216-F-0101	0.59	0.10	1.00	-	-	61	6.9	177	1.6
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 3)	118-F-0301	10.09	1.19	11.41	-	-	61	10.2	155	4.9
MAA	Unit 187 - Coke Handling	19 point sources	0.06	0.01	0.11	-	-	Varied from 3 to 17	2	1.6	50
Emission Total			**123.9**	**15.7**	**94.9**	**0.9**	**0.0**	**N/A**	**N/A**	**N/A**	**N/A**

* Denotes Normal Temperature and Pressure Conditions (NTP: 0°C and 1.013 bara)

Notes: 1. For the normal operating case all boilers are assumed to burn gaseous fuel.
2. The emissions for Unit 136 (MAA) & Unit 111 (at MAB) correspond to the combined emissions from two stacks.
3. The emissions from Unit 156 (at MAB) correspond to the flue gas after treatment and are based on two shifts per day.
4. The emissions from Unit 11 are dual fired (gas & liquid), for normal emissions it is assumed to burn gaseous fuel.
5. For unit 25/26 and Unit 11 which are existing revamped units, 20% of the emissions provided are modelled as part of the CFP as this is the incremental increase.

Table 9.9: Point Emission Sources and Emission Levels (Maximum Case for New Sources)

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
MAA	Unit 135 DCU-NHTU	135-F-0101	0.1	0.00001	0.1	-	-	61	9.1	321	0.5
	Unit 136 DCU[2]	136-F-0201A/B	5.4	0.3	3.2	-	-	61	5.0	180	3.3
	Unit 137 DIP Reboiler Heater	137-F-0101	3.2	0.2	1.9	-	-	61	8.2	218	2.3
	Unit 141 ARDS	141-F-0201	1.3	0.2	0.8	-	-	65	7.4	150	1.5
		141-F-0401	1.4	0.2	0.8	-	-	65	7.4	150	1.5
	Unit 148 HPU	148-F-0301	9.6	0.04	5.7	-	-	61	10.3	154	2.8
	Unit 129 Steam Boilers[1]	129-F-0201A	7.7	0.48	4.64	-	-	65	7.6	293	4.1
		129-F-0201B	7.7	0.48	4.64	-	-	65	7.6	293	4.1
		129-F-0201C	7.7	0.48	4.64	-	-	65	7.6	293	4.1
	Unit 151/152 TGTU	151-F-0132	1.2	3.2	0.03	0.06	-	61	14*	270	1.4
	Unit 151/152 TGTU	152-F-0132	1.2	3.2	0.03	0.06	-	61	14*	270	1.4
	Unit 183 VRU	183-F-0101	3.0	0.2	1.8	-	-	61	6.8	204	2.1
	Unit 186 FCC-NHTU HDS	186-F-0201	0.1	0.03	0.2	-	-	65	6.3	363	1.0
		186-F-0202	0.2	0.03	0.3	-	-	65	6.3	372	1.1
	Unit 25/26 NHT Charge Heater (revamp existing) [4]	H25-101	0.2	-	0.3	-	-	31.6	1.3	329	1.3
		H26-101	0.2	-	0.3	-	-	31.6	1.3	329	1.3
	Unit 107 Isomerization	107-F-0101	0.4	0.1	0.7	-	-	61	5.1	293	1.8
		107-F-0102	5.5	0.3	3.3	-	-	61	5.1	188	3.5
	Unit 144 GOD	144-F-0101	0.3	0.1	0.5	-	-	61	8.2	329	1.2
MAB	Unit 111 Crude Distillation - 2 Heaters[2]	111-F-0101A/B	11.0	11.3	4.6	-	0.9	61	5.3	177	4.5
	Unit 112 ARDS Reactor Feed Furnace Train 1	112-F-0101	1.5	0.2	0.9	-	-	65	7.6	150	1.5
	Unit 112 ARDS Reactor Feed Furnace Train 2	112-F-0201	1.5	0.2	0.9	-	-	65	7.6	150	1.5
	Unit 112 ARDS Atmospheric Fractionator Feed Furnace	112-F-0401	3.7	3.8	1.6		0.3	65	7.4	150	2.2

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
	Unit 212 ARDS Reactor Feed Furnace	212-F-0101	1.5	0.2	0.9	-	-	65	7.6	150	1.5
	Unit 212 ARDS Atmospheric Fractionator Feed Furnace	212-F-0401	1.1	1.9	0.8	-	0.2	65	7.4	150	1.6
	Unit 114 Hydrocracker 1st Stage Gas Heater	114-F-0101	0.3	0.1	0.5	-	-	61	5.1	159	1.6
	Unit 114 Hydrocracker 2nd Stage Gas Heater	114-F-0102	0.4	0.1	0.7	-	-	61	5.2	159	1.7
	Unit 114 Hydrocracker Product Fractionator Feed Furnace	114-F-0103	5.4	0.3	3.2	-	-	61	10.1	159	4.0
	Unit 115 KHT Reactor Feed Furnace	115-F-0101	0.1	0.03	0.2	-	-	61	7.6	413	1.3
	Unit 116 DHT Reactor Feed Furnace	116-F-0101	1.7	0.1	1.0	-	-	61	15	216	1.8
	Unit 117 NHT Reactor Feed Furnace	117-F-0101	0.03	0.00001	0.1	-	-	61	7.6	397	0.5
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 1)	118-F-0101	12.1	1.4	13.7	-	-	61	11.6	155	5.0
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 2)	118-F-0201	12.1	1.4	13.7	-	-	61	11.6	155	5.0
	Unit 123 SRU-TGTU Tail Gas Incinerator	123-F-0132	2.4	7.08	2.2	1.22	-	61	15*	270	1.7
	Unit 123 SRU-TGTU Tail Gas Incinerator	123-F-0232	2.4	7.08	2.2	1.22	-	61	15*	270	1.7
	Unit 123 SRU-TGTU Tail Gas Incinerator	123-F-0332	2.4	7.08	2.2	1.22	-	61	15*	270	1.7
	Unit 127 CCR Reactor Feed Furnace [2]	127-F-0101, 0102, 0103, 0104	1.4	0.2	2.3	-	-	61	10.8	193	2.6
	Unit 127 CCR Stabilizer Reboiler	127-F-0105	0.1	0.03	0.2	-	-	61	10.5	283	0.9

Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	CO g/s	H2S g/s	TSP g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
	Unit 213 VRU Vacuum Charge Heater	213-F-0101	2.4	0.1	1.4	-	-	61	5.7	204	2.2
	Unit 11 CDU Fired Heater (existing) [4]	H-11-101	*18.7*	*59.9*	*2.0*	-	4.0	70	16.2	184.4	2.5
	Unit 131 Steam System Utility Boiler	131-F-0201A	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
		131-F-0201B	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
		131-F-0201C	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
		131-F-0201D	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
		131-F-0201E	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
		131-F-0201F	4.0	4.1	1.7	-	0.3	65	7.6	293	2.6
	Unit 156 WWT Oily Sludge Incinerator	156-A-0209-F01	0.1	-	0.1	-	-	20	7.6	950	0.9
	Unit 214 Hydrocracker - 3 Heaters Combined [2]	214-F-0101/0102/0103	5.6	0.4	4.1	-	-	61	5.1	136	3.7
	Unit 116 DHT Reactor Feed Furnace	116-F-0101	2.0	0.1	1.2	-	-	61	8.2	177	1.6
	Unit 118 H2 Plant Tubular Reformer Furnace (Train 3)	118-F-0301	12.1	1.4	13.7	-	-	61	12.2	155	4.9
MAA	Unit 187 - Coke Handling	19 point sources	-	-	-	-	0.003122	Varied from 3-17	2	1.6	50
Emission Total			**182.4**	**112.1**	**118.4**	**0.5**	7.2	N/A	N/A	N/A	N/A

*Denotes Normal Temperature and Pressure Conditions (NTP: 0°C and 1.013 bara)

Note: The SRU releases for the maximum case (Unit 151/152 & Unit 123) are based on SRU emergency case 1 for SO_2 emissions.

Notes:

1. For the maximum operating case, the fired duty for the Unit 129 boilers (at MAA) is increased by 20% (from the normal operating case).
2. For the boilers at Unit 131 (at MAB Fired equipment has dual fuel capability. For contingency/maximum case it is assumed that equipment item is fired 85% on fuel gas and 15% on fuel oil. This ratio is intended to ensure compliance with applicable Kuwait EPA point source emission limits.
3. The emissions for Unit 111, Unit 127, Unit 214 (at MAB) and Unit 136 (at MAA) correspond to the combined emissions from two stacks.
4. For Unit 25/26 and Unit 11 which are existing revamped units, 20% of the emissions provided are modelled as part of the CFP as this is the incremental increase.

Table 9.10: Point Emission Sources and Emission Levels (Decommissioned Sources)

Refinery	Name	Unit (Tag No.)	NOx	SO2	CO	TSP	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
			g/s	g/s	g/s	g/s				
SHU	Hydrogen manufacturing	H-02-01N	7.55	3.66	0.11	-	52.21	8.87	427	3.66
		H-02-01S	7.21	3.91	0	-	52.21	8.87	427	3.66
		H-02-51N	7.21	4.15	0	-	52.21	8.87	427	3.66
		H-02-51S	10.3	3.91	0	-	52.21	8.87	427	3.66
	Crude & Vacuum	H-06-01N	2.05	0.3	0	-	40.54	11.6	465	1.45
		H-06-01S	0.8	2.18	0	-	40.54	11.6	465	1.45
		H-06-02N	1.55	1.2	0.154	-	40.54	11.6	465	1.45
		H-06-02S	0.8	1.22	0	-	40.54	11.6	465	1.45
		H-06-03N	3.23	1.68	0	-	45.03	7.94	425	2.27
		H-06-03S	3.51	0.93	0	-	45.03	7.94	425	2.27
		H-06-04	1.62	0.06	0	-	26.09	9.3	525	1.71
	Hot Oil	H-07-01A	1.281	0.038	0	-	27.43	11	698	1.3
		H-07-02AN	1.53	0.131	0.114	-	28.96	10.3	652	1.75
		H-07-02AS	1.74	0.07	0.03	-	28.96	10.3	652	1.75
		H-07-01B	1.03	0.04	0.017	-	27.43	10.9	694	1.3
		H-07-02BN	1.06	0.061	0	-	28.96	9.6	593	1.75
		H-07-02BS	1.31	0.122	0	-	28.96	9.6	593	1.75
	Isomax	H-08-01	0.482	0.03	0	-	35.36	9.6	737	1.22
		H-08-02	5.02	0.265	0	-	40.39	10.8	654	2.44
	Naphtha Fractionation	H-09-01	4.48	0.942	0	-	40.39	11	688	2.44
	Kero Unifiner	H-11-02	2.08	0.05	0.044	-	32.92	9.27	567	1.62
		H-11-03	1.19	0.038	0.065	-	30.48	9.6	603	1.37
		H-11-04	2.57	0.07	0	-	33.83	12	733	1.68
		H-11-05	2.12	0.162	0	-	35.05	10	733	1.98
		H-11-06	1.02	0.036	0	-	31.39	9.29	558	1.37
	Diesel Unifiner	H-12-01	1.48	0.194	0.022	-	30.48	6	629	1.98

Refinery	Name	Unit (Tag No.)	NOx	SO2	CO	TSP	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
			g/s	g/s	g/s	g/s				
		H-12-04	0.907	0.093	0	-	27.89	7.6	624	1.4
	Heavy Diesel Unifiner	H-13-01	1.35	0.156	0	-	30.48	12.7	624	1.22
		H-13-03	0.874	0.067	0	-	30.48	8.6	504	1.37
	Hot Oil Vacuum	H-63-01	0.381	37.84	5.2	-	66.45	5.84	233	1.75
	Isocracker	H-68-02W	0.94	0.0372	0.05	-	49.07	5.88	372	1.75
		H-68-02E	1.08	0.0372	0.065	-	49.07	5.88	372	1.75
	Hydrogen manufacturing	H-62-01aN	15.44	6.1	0	-	52.21	8.87	427	3.66
		H-62-01aS	17.73	4.88	0	-	52.21	8.87	427	3.66
	Boilers	B-20-01A	11.02	9.4	0	-	18.29	16.18	407.4	2.97
		B-20-01B	15.7	13.52	0	-	18.29	16.18	407.4	2.97
		B-20-01C	17.36	20.27	0	-	18.29	16.18	407.4	2.97
		B-20-01D	17.17	22.62	1.672	-	18.29	16.18	407.4	2.97
	Catalytic Reformer	H-05-01W	6.04	0	0	-	24.69	14.67	815.71	3.05
		H-05-01M	1.51	0	0	-	24.69	14.67	815.71	1.52
		H-05-01E	3.1	0.1002	0	-	24.69	14.67	815.71	1.83
	Naphtha Unifiner	H-10-01	1.53	0.1043	0	-	30.78	11	749.04	1.52
	Diesel Unifiner	H-12-02	1.43	0.2421	0	-	30.48	6	627	1.98
		H-12-03	0.914	0.1547	0	-	28.5	8	626.82	1.37
	Isocracker	H-68-01W	0.94	0.0372	0.05	-	33.83	5.52	468.48	1.52
		H-68-01E	1.08	0.0372	0.065	-	33.83	5.52	468.48	1.52
MAA	MAA-CDU # 3	H-03-070	2.922	0.142	0	-	62.48	7.42	261	3.05
MAB	MAB-Crude	H-01-101	1.012	0.611	0.0713	-	21	8.53	483	1.53
		H-01-102	0.993	0.652	1.59	-	21	8.53	483	1.53
		H-01-104	1.452	0.326	0.0713	-	21	8.53	483	1.53
		H-01-105	0.382	0.326	0.0713	-	21	8.53	483	1.53
		H-01-106	1.051	1.386	0.321	-	21	8.53	483	1.53
		H-01-107	1.146	0.652	0.1783	-	21	8.53	483	1.53

Refinery	Name	Unit (Tag No.)	NOx	SO2	CO	TSP	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
			g/s	g/s	g/s	g/s				
		H-01-108	1.051	1.306	0.1605	-	21	8.53	483	1.53
		H-01-109	1.719	0.163	0	-	21	8.53	483	1.53
		H-01-110	1.528	0.937	0	-	21	8.53	483	1.53
	MAB-RCD Unibon	H-02-101A	0.264	0.01	0.009	-	20	0.95	511	2.29
		H-02-101B	0.259	0.01	0.0045	-	20	0.95	511	2.29
		H-02-102	0.317	0.01	0.0086	-	20	0.91	511	2.29
	MAB-Hydrogen Plant	H-03-101	1.377	0.132	0.2455	-	43.1	2.13	288	2.75
SHU	Unit 74 SHU	H-74-001	2.17	118	24.31	-	61	7.04*	270	1.4
		H-74-002	2.38	70.35	41.25	-	61	7.04*	270	1.4
MAA	Unit 99 MAA	ST-93-001	0	173.9	0	-	61	7.55*	270	1.7
	ESP on Unit 86	ST-86-301	0	0	0	19.1	73.15	9.07*	285	2.44
	Emission Total		**210.7**	**510.1**	**75.9**	**19.1**	**N/A**	**N/A**	**N/A**	**N/A**

* Denotes Normal Temperature and Pressure Conditions (NTP: 0°C and 1.013 bara)

Table 9.11: Flare Emissions during Emergency

Refinery / Flare	Tag No.	Emergency Scenario/Governing Case	NOx	SO2	Height above ground (m)	Effective Height (m)	Exit Velocity (metres/sec)	Exit Temp. (°C)	Effective Exit Diameter (m)
			g/s	g/s					
MAA Unit 162	162-A-0101	Case 2	0.15	2061	108	118	40	1000	1.06
MAA Unit 167	167-A-0101	Case 2	-	8163	91	108	40	1000	2.04
MAA Unit 25/26	-	Case 2	-	420	144	269.2	40	1000	22.18
MAA Unit 39	ST-39-001	Case 1	-	522	67.1	108.7	40	1000	5.34
		Case 2	-	433	67.1	77.1	40	1000	0.85
		Case 4	-	1.25	67.1	110.3	40	1000	5.51
		Case 5	4.9	44	67.1	69.6	40	1000	0.22
MAB Unit 146	146-A-0101A	Case 2	-	28247	36.6	64.1	40	1000	3.84
MAB Unit 149 HP HC	149-A-0112A	Case 2	0.15	1237	61	69.3	40	1000	0.85
MAB Unit 149 LP HC	149-A-0102A	Case 2	1.4	1774	64	141.7	40	1000	11.74
MAB Unit 249	249-A-0101	Case 2	146	10293	77	162.7	40	1000	14.08
MAB Unit 314 HP HCR	314-A-0112A	Case 3	3.31	439	85	131.2	40	1000	6.37

Notes:
1. Each emergency flare case is modelled separately.
2. Each flare emergency case is modelled without taking into account the contribution from new or decommissioned sources, as their contribution will be negligible compared to the actual flare emission.
3. All flares have been modelled as single stacks.
4. The emergency flare scenario numbering and data are based on information provided by Fluor.
5. The CFP project scope includes the flare for MAB Unit 314 (LP HCR flare), but as it does not have any hydrogen sulphide in its feed it has not been considered for air quality purposes.

Table 9.12: Total Power Failure Flare Emissions

Refinery / Flare	Tag No.	Emergency Scenario/Governing Case	NOx	SO2	Height above ground (m)	Effective Height (m)	Exit Velocity (metres/sec)	Exit Temp. (°C)	Effective Exit Diameter (m)
			g/s	g/s					
MAA Unit 162	162-A-0101	Case 1 - TPF	5.63	985	108	216.2	40	1000	16.4
MAA Unit 167	167-A-0101	Case 1 – TPF	-	628	91	96.9	40	1000	0.89
MAA Unit 25/26	-	Case 1 – TPF	-	219	144	244.9	40	1000	16.57
MAA Unit 39	ST-39-001	Case 3 – TPF	-	523	67.1	108.7	40	1000	5.15
MAA Unit 62	ST-62-201N	Case 1 – TPF	2910	27074	110	140.2	40	1000	4.57
MAB Unit 146	146-A-0101A	Case 1 – TPF	-	2112	36.6	46	40	1000	1.64
MAB Unit 149 HP HC	149-A-0112A	Case 1 – TPF	25	20849	61	167.4	40	1000	18.63
MAB Unit 249	249-A-0101	Case 1 – TPF	4.9	412	77	110.7	40	1000	4.06
MAB Unit 314 HP HCR	314-A-0112A	Case 1 - TPF	-	14754	85	217.7	40	1000	23.41

Notes:

1. The Total Power Failure (TPF) scenario incorporates all the emergency flaring events from each refinery (i.e. all TPF cases are modelled together at both MAA and MAB).
2. The TPF case is modelled without taking into account the contribution from new or decommissioned sources, as their contribution will be negligible compared to the actual flare emission.
3. All flares have been modelled as single stacks, with the exception of MAA Unit 25/26, where two identical flare stacks have been assumed. Note that parameters indicated in the table are per stack.
4. The emergency flaring data are based on information provided by Fluor.
5. The CFP project scope includes the flare for MAB Unit 314 (LP HCR flare), but as it does not have any hydrogen sulphide in its feed it has not been considered for air quality purposes (for the Total Power Failure Case).

Table 9.13: SRU Emissions during Upset conditions

Upset Condition	Refinery	Name	Unit (Tag No.)	NOx g/s	SO2 g/s	H2S g/s	Height above gl (m)	Exit Velocity (m/s)	Exit Temp. (°C)	Exit Diameter (m)
Upset 1	MAA	Unit 151 MAA	151-A-0131	1.16	204.72	0.11	61	14*	270	1.4
(SRU Case 2)			152-A-0131	0.78	0.68	0.06	61	14*	270	1.4
	MAB	Unit 123 MAB	123-A-0131	2.36	461.7	0.25	61	15*	270	1.7
			123-A-0231	1.67	1.472	0.25	61	15*	270	1.7
			123-A-0331	1.67	1.472	0.25	61	15*	270	1.7
Upset 2	MAA	Unit 151 MAA	151-A-0131	0.03	80.56	86.39	61	14*	150**	1.4
(SRU Case 3)			152-A-0131	0.78	0.68	0.06	61	14*	150**	1.4
	MAB	Unit 123 MAB	123-A-0131	0.0	178.67	190.92	61	15*	150**	1.7
			123-A-0231	1.67	1.472	0.25	61	15*	150**	1.7
			123-A-0331	1.67	1.472	0.25	61	15*	150**	1.7

* Denotes Normal Temperature and Pressure Conditions (NTP: 0°C and 1.013 bara)

** Denotes for Case 3, temperature change from 270 °C to 150 °C due to shutdown of TGTU.

Note

1. The results for each SRU upset scenario are combined with the normal emission case scenario for the CFP sources, but not the decommissioned modelling scenario.
2. Data is based on Rev D data provided by Fluor.
3. Modelling scenarios assume that only one SCOT (Case 2) or one SCOT and one TGTU (Case 3) at either refinery is out of operation at any given point in time (i.e. for other units normal emission data have been used).

Table 9.14 –Maintenance/Shutdown Emissions Scenario at MAA

Maintenance Scenario	Refinery	Status	Name	Unit (Tag No.)	SO2 g/s
Maintenance 1	MAA CFP	Running	Unit 107	107-F-0101	1.2777
RMP Block Shutdown				107-F-0102	5.7222
	MAA CFP	Shutdown	Unit 144	144-F-0101	0.04
	MAA Existing	Shutdown	KD Unit	H-40-001	0.3801
	MAA Existing	Shutdown		H-43-001	0.0194
	MAA Existing	Shutdown	ARDS 1	41-H001	0.0210
	MAA Existing	Shutdown		41-H-002	0.0410
	MAA Existing	Shutdown		41-H-003	0.0175
	MAA Existing	Shutdown	ARDS2	42-H001	0.000
	MAA Existing	Shutdown		42-H001	0.0410
	MAA Existing	Shutdown	HP-1	H-48-001	0.0957
	MAA Existing	Shutdown	HP-2	H-49-001	0.0957
	MAA Existing	Shutdown	SR/TGT	ST-54-001	48
Maintenance 2	MAA CFP	Running	Unit 137	137-F-0101	3.3055
CFP Block Shutdown	MAA CFP	Shutdown	Unit 129	129-F-0201A	0.3
	MAA CFP	Shutdown		129-F-0201B	0.3
	MAA CFP	Shutdown		129-F-0201C	0.3
	MAA CFP	Shutdown	Unit 135	135F-0101	0.01
	MAA CFP	Shutdown	Unit 136	136-F-0201A/B/C	0.28
	MAA CFP	Shutdown	Unit 141	141-F-0201	0.13
	MAA CFP	Shutdown		141-F-0301	0.17
	MAA CFP	Shutdown	Unit 148	148-F-0301	0.03
	MAA CFP	Shutdown	Unit 151	151-F-0132	0.67
	MAA CFP	Shutdown	Unit 152	152-F-0132	0.67
	MAA CFP	Shutdown	Unit 183	183-F-0101	0.16

Note: The units with a shutdown status have been modelled as decommissioned units.

Table 9.15 - Comparison of Total Pollutant Emissions from New CFP Sources (Normal Case) against Decommissioned Sources

Case / Sources	Total Pollutant Emission (g/s)	
	NOx	SO2
New CFP Sources (Normal Case)	123.9	15.7
Decommissioned Sources	210.7	510.1
Total *Reduction* Post CFP (g/s)	86.8	494.4

Total emissions from decommissioned units are far greater than the overall emissions for the new CFP units, particularly for SO_2. These differences are primarily due to the decommissioned boilers, as well as improvements at Unit 99 TGTU (due to new pollution control SCOT Unit that will be commissioned to improve SO_2 emissions from existing MAA SRU).

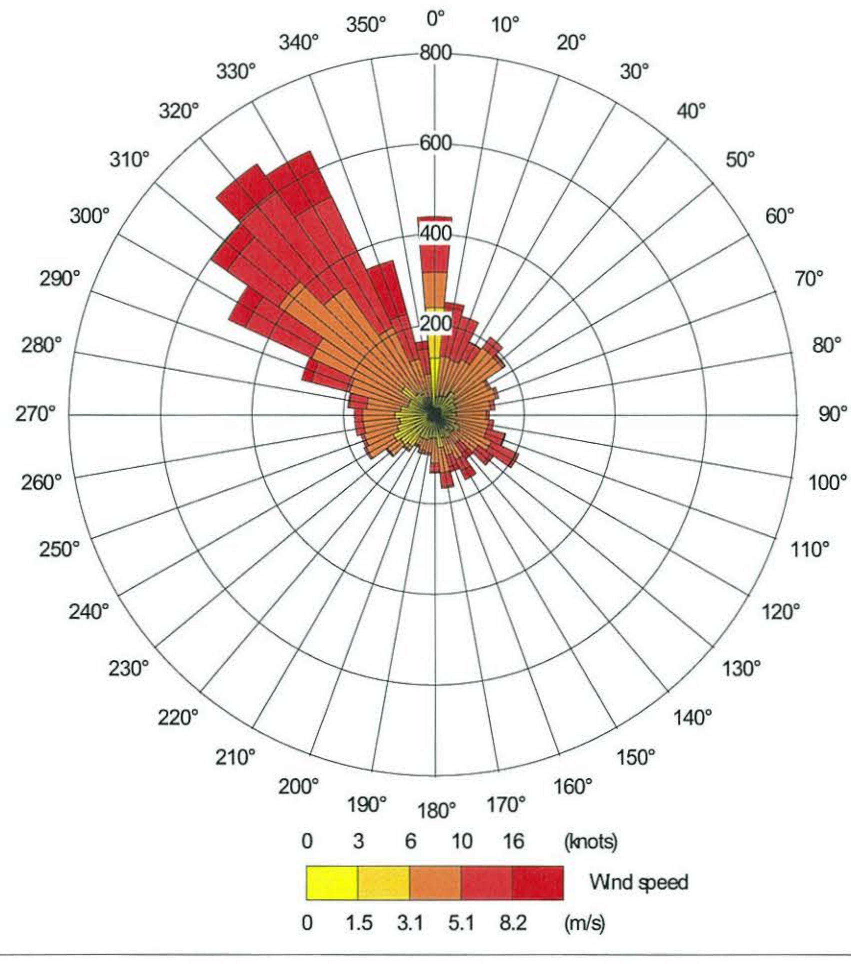
Overall, it is clear that air quality in the area should generally improve as a result of the CFP project.

9.4.4 Meteorological Data

Meteorological data provided by KISR/KNPC (as hourly sequential data), for a period of two years (2005 and 2006), from a measuring station located in the Umm Al Haiman area (south of the MAB refinery) has been used in the modelling. Sequential meteorological data from 2005 have been used to conduct the air modelling (more complete data-set than 2006).

These data were imported into ADMS 4 to produce the wind rose displayed in the figure below. The wind rose shows the predominant directions from which the wind blows. It can be seen that the wind typically blows from the North-West.

Figure 9.8: Wind Rose



9.4.5 K-EPA and Kuwait Ministry of Oil Criteria

The criteria used in the assessment are presented in Appendix C of the CFP Project EBS Report (DNV No. 32317425 / Fluor Doc. No. P6000CFP.000.10R.02), while Table 9.16 summarises the key parameters under investigation in this study, i.e. the long term and short term industrial and residential criteria for NO_2, SO_2, H_2S, CO and TSP. It is noted here that the results were compared against the most stringent criteria from the K-EPA and Ministry of Oil criteria.

Table 9.16: Maximum Permitted Ground Level Concentrations for Pollutants Based on K-EPA / MOO Criteria

Pollutant	Industrial ST (99.7%ile 1-hour average)	Industrial LT (Annual)	Residential ST (99.7%ile 1-hour average)	Residential LT (Annual)	On-Site Occ Exp Short Term[1]	On- site Occ Exp Long Term [1]
	µg/m³	µg/m³	µg/m³	µg/m³	ppm	ppm
NO_2	225	67	225	67	5** (9345)	-
SO_2	782.5	80	444	80	5* (13000)	2 *(5000)
H_2S	40	8	40	8	15* (20720)	10* (14000)
CO	34000	-	34000	-	-	-
TSP	317.5#	75	317.5#	75	-	-

1 Numbers in brackets are the equivalent µg/m³ concentrations.

* Occupational health levels are based on KNPC HSE Exposure standards for short term (15-minutes) and long term (8-hour) exposure (SHE-TSOH-04-4301).Limits are the identical to K-EPA Appendix No. 3(1).

** No limit is provided by KNPC HSE; hence the applicable short term exposure limit (15-minutes) from ACGIH (American Conference of Industrial Hygienists) has been used for the purposes of this study.

The short term industrial and residential limits for the 1-hour average concentration averages have been converted from daily averaged concentrations.

9.4.6 Modelling Results

The primary objective for this part of the study is to examine the impact of the CFP Project on the air quality in the area. The sources that are to be decommissioned as part of the project will have a "negative" effect on the ambient air quality (i.e. air quality will improve), whereas the new units added will have a "positive" effect. The results of the "Decommissioned Emission" Scenario are combined with the "Normal Emission" / "Maximum Emission" Scenarios. The estimated, combined ADMS ground level concentrations for the various pollutants at the monitoring point locations are combined with the ambient baseline data concentrations (see Section 9.2.3), and then compared to the relevant criteria (refer to Table 9.16).

Details of the scenarios run, and the results of the "Decommissioned Emission", "Normal Emission" and "Maximum Emission" Scenarios are presented below.

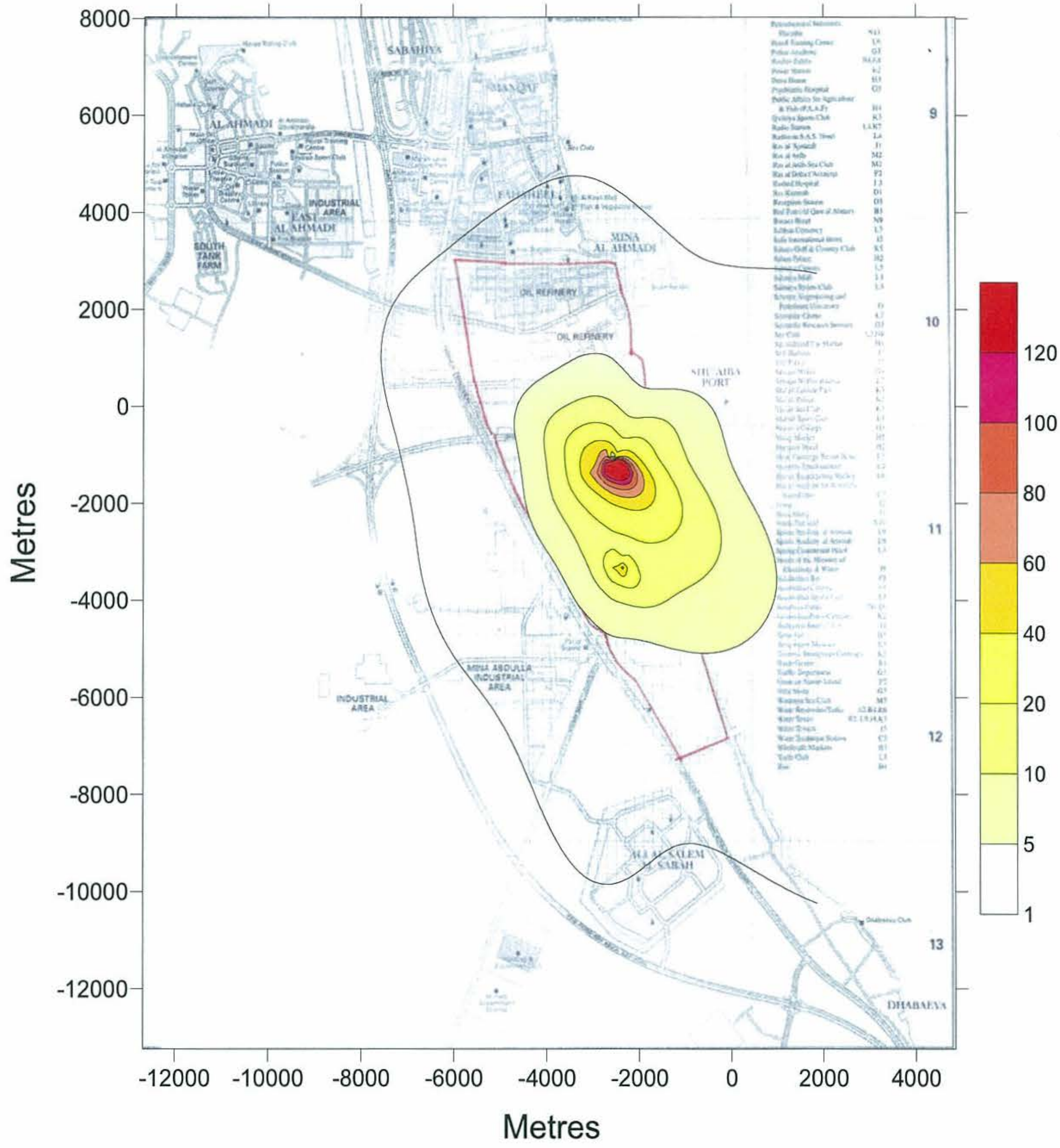
9.4.6.1 Combined "Normal Emission" + "Decommissioned Emission" Scenario

This will be the "Base Case" after the completion of the project, and reflects the overall project normal operating conditions for the refineries after the CFP is operating and SHU process units,along with other process units at MAA and MAB (refer to Table 9.5), are decommissioned. It has been modelled as follows:

- New "Normal Emission" model (sources from Table 9.8) combined with the "Decommissioned Emission" model (sources from Table 9.10) to produce the ground level concentration contours for the various pollutants
- The combined, predicted ADMS concentrations at the monitoring point locations are combined with the baseline air quality data, in order to obtain an estimated of the future air quality in the area, and then compared against the relevant K-EPA / MOO criteria.

The long term (annual average) and short term (99.7%ile 1-hour average) results dispersion contours are presented in the figures that follow for NO_x, SO_2, H_2S and TSP. All results are presented in $\mu g/m^3$. The contour plots do not include the background concentration data. For the NO_x case, contours are presented for the "Decommissioned Emission" and "Normal Emission" Scenarios, as well as the combined plot. For the other pollutants only the combined plots are provided for simplicity. It is noted here that the NO_2 concentrations are assumed to correspond to 10% of the overall NO_x concentration.

Figure 9.9: NO_x Annual Average Data ("Decommissioned Case")



Note: The contours represent improvement in the air quality.
All results are presented in $\mu g/m^3$.

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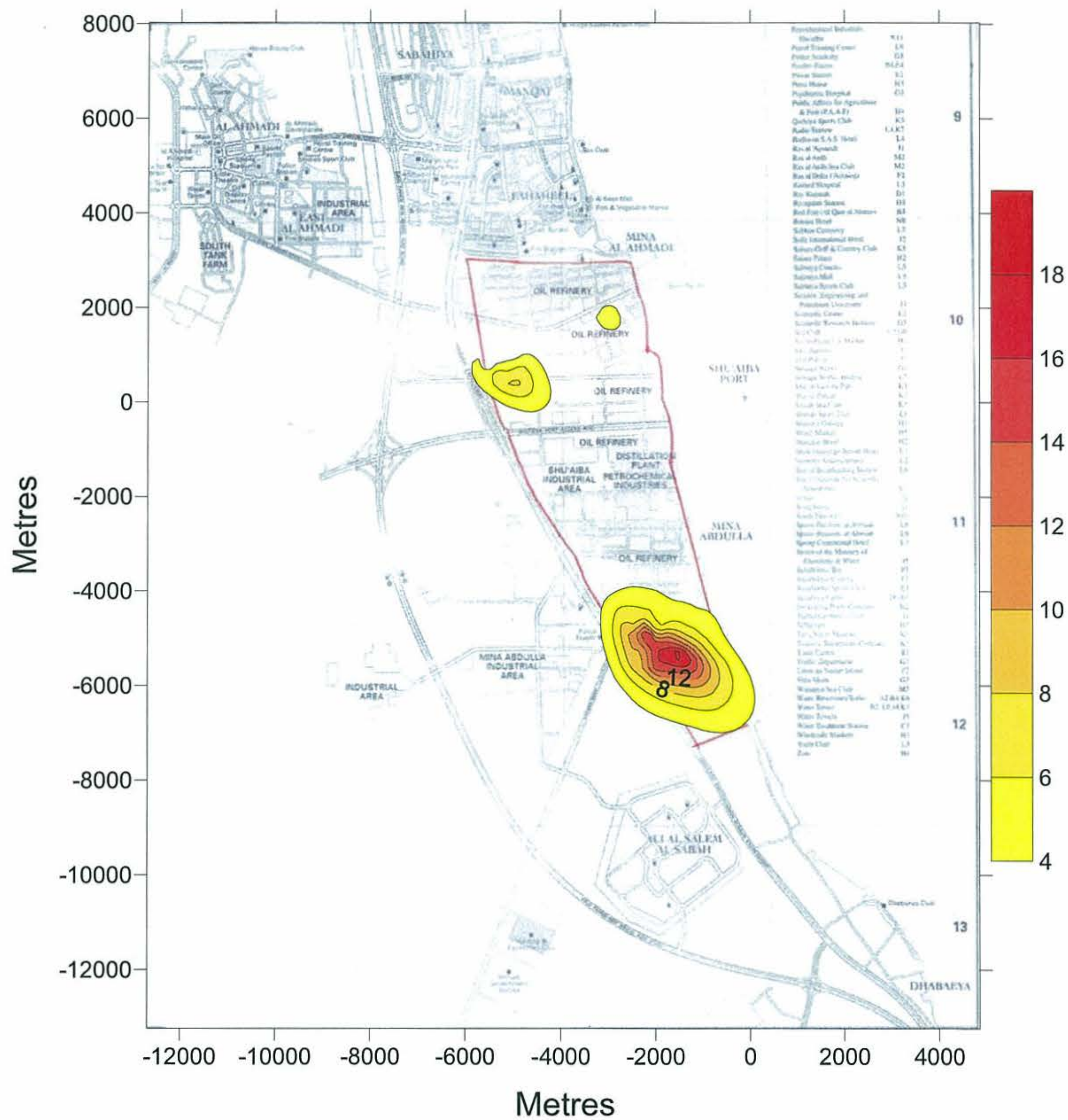
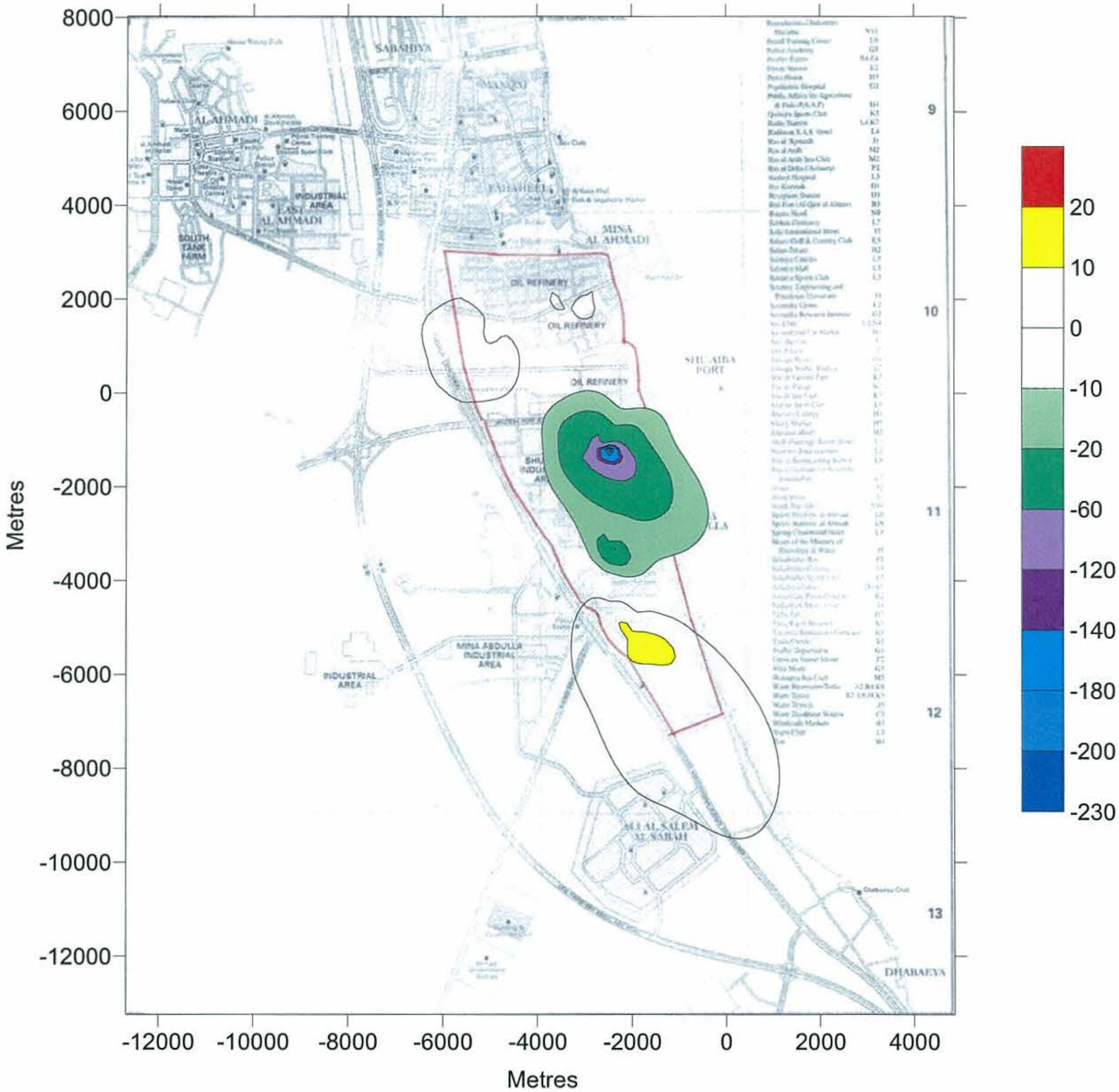
Figure 9.10: NO_x Annual Average Data ("New Normal Case")



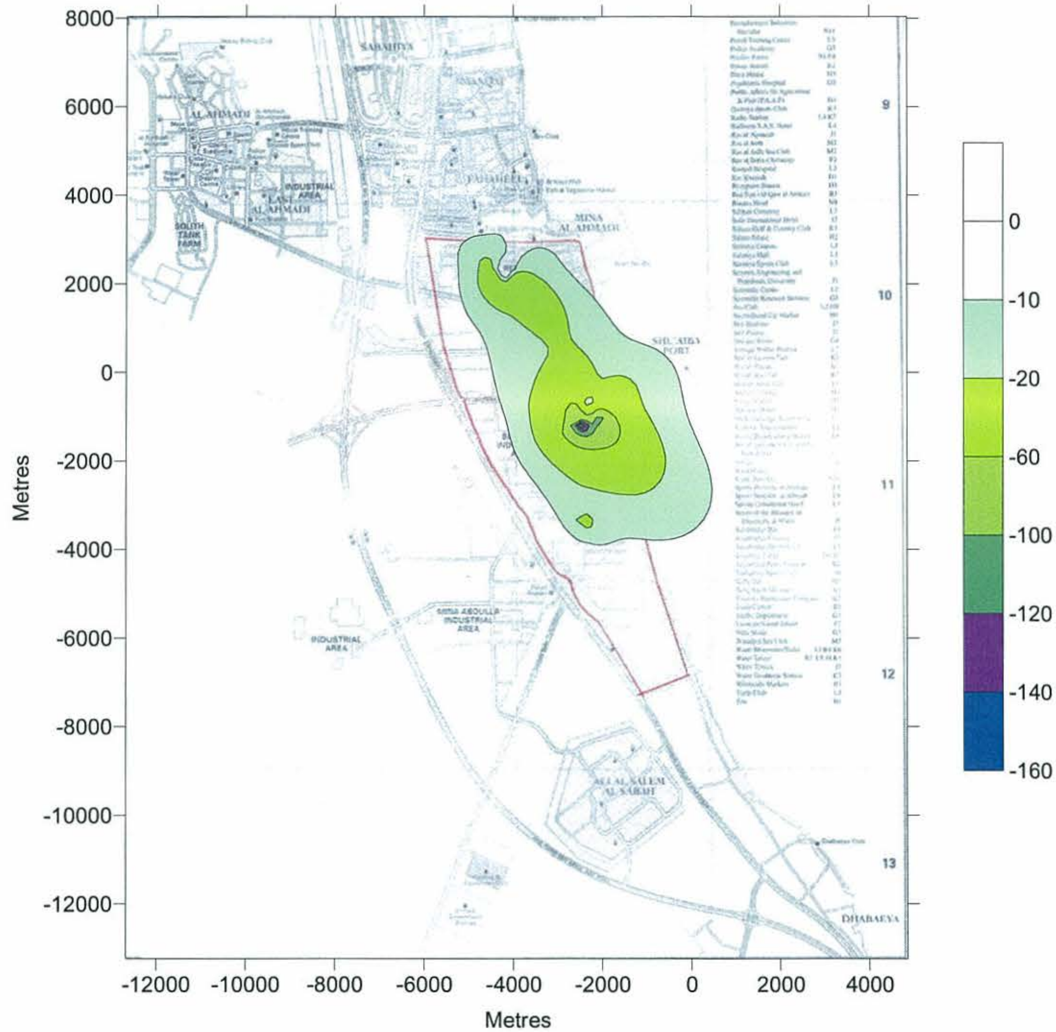
Note: The contours represent deterioration in the air quality.
All results are presented in $\mu g/m^3$.

Figure 9.11: NO_x Annual Average Data (Combined - "Base Case")



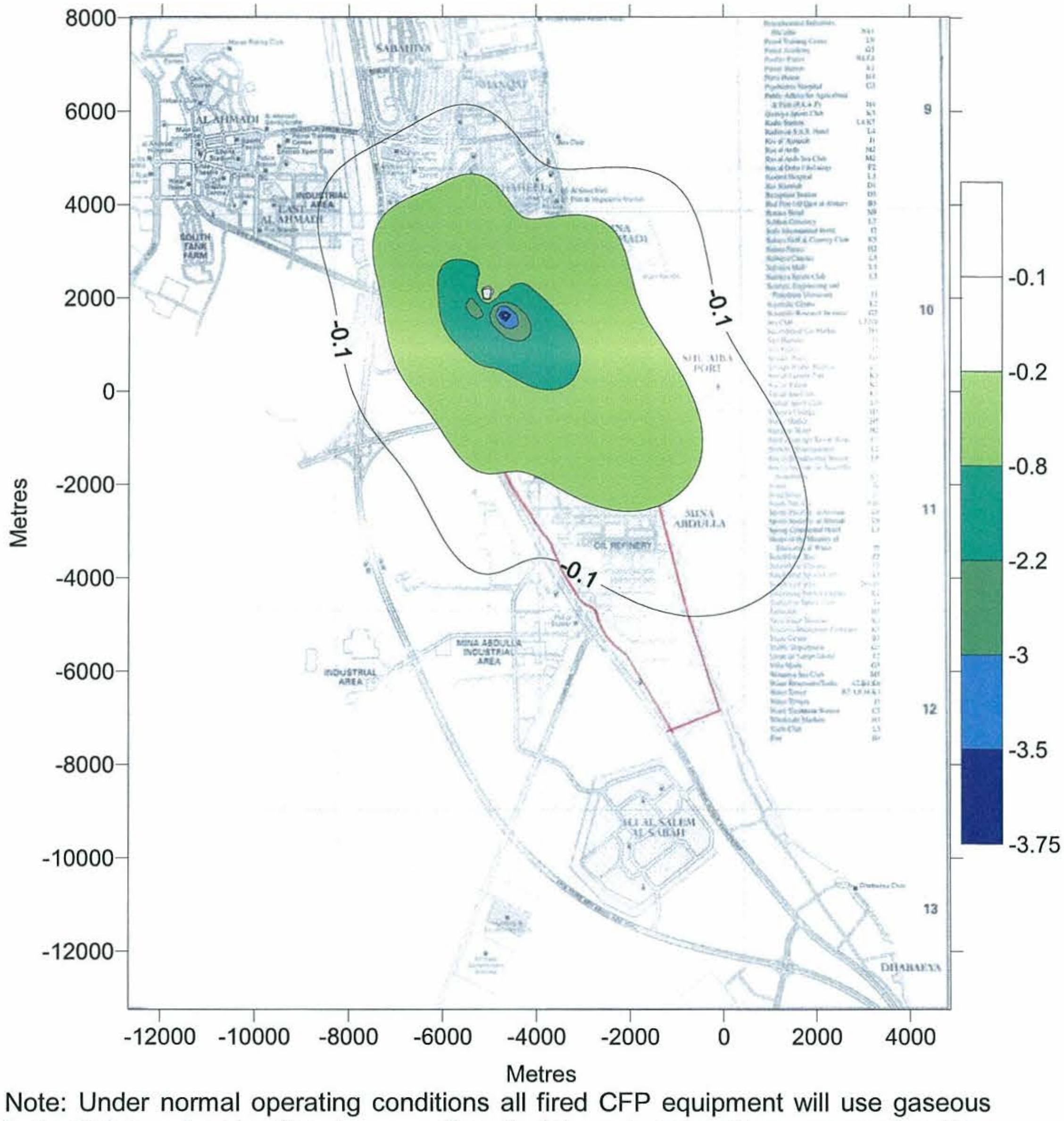
Note: The contours show both improvement and deterioration in the air quality.
All results are presented in $\mu g/m^3$.

Figure 9.12: SO_2 Annual Average Data (Combined - "Base Case")



Note: The contours show improvement in the air quality. All results are presented in $\mu g/m^3$.

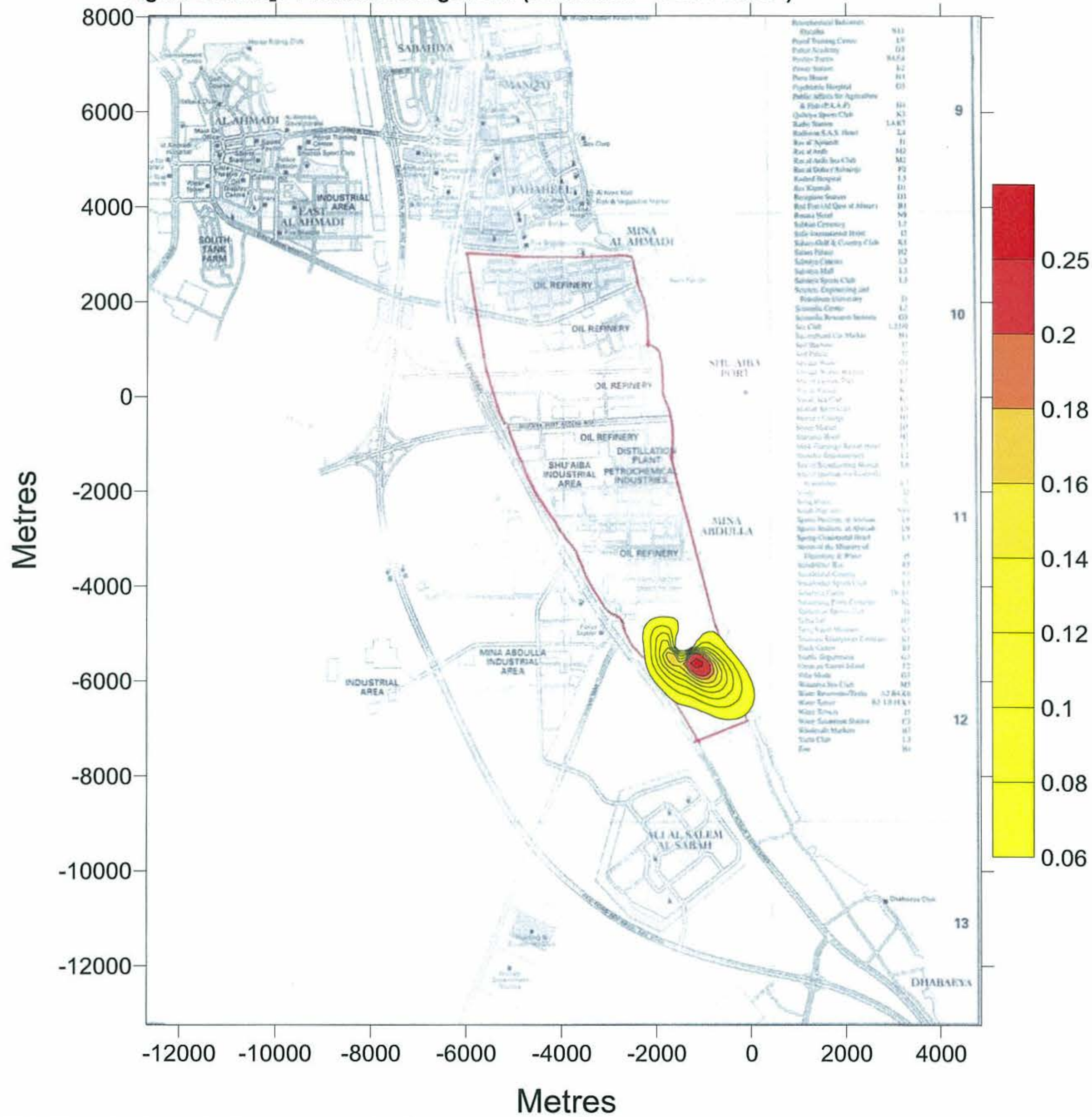
Figure 9.13: TSP Annual Average Data (Combined - "Base Case")



Note: Under normal operating conditions all fired CFP equipment will use gaseous fuel which is not a significant source of particulate emissions. The new coke handling facility at MAA (Unit 187) has the potential for significant particulate emissions but it will be tightly controlled, hence there will only be an overall improvement in the TSP levels which is reflected in the above figure, as the model also incorporates the installation of an ESP within the FCCU at MAA.

All results are presented in $\mu g/m^3$.

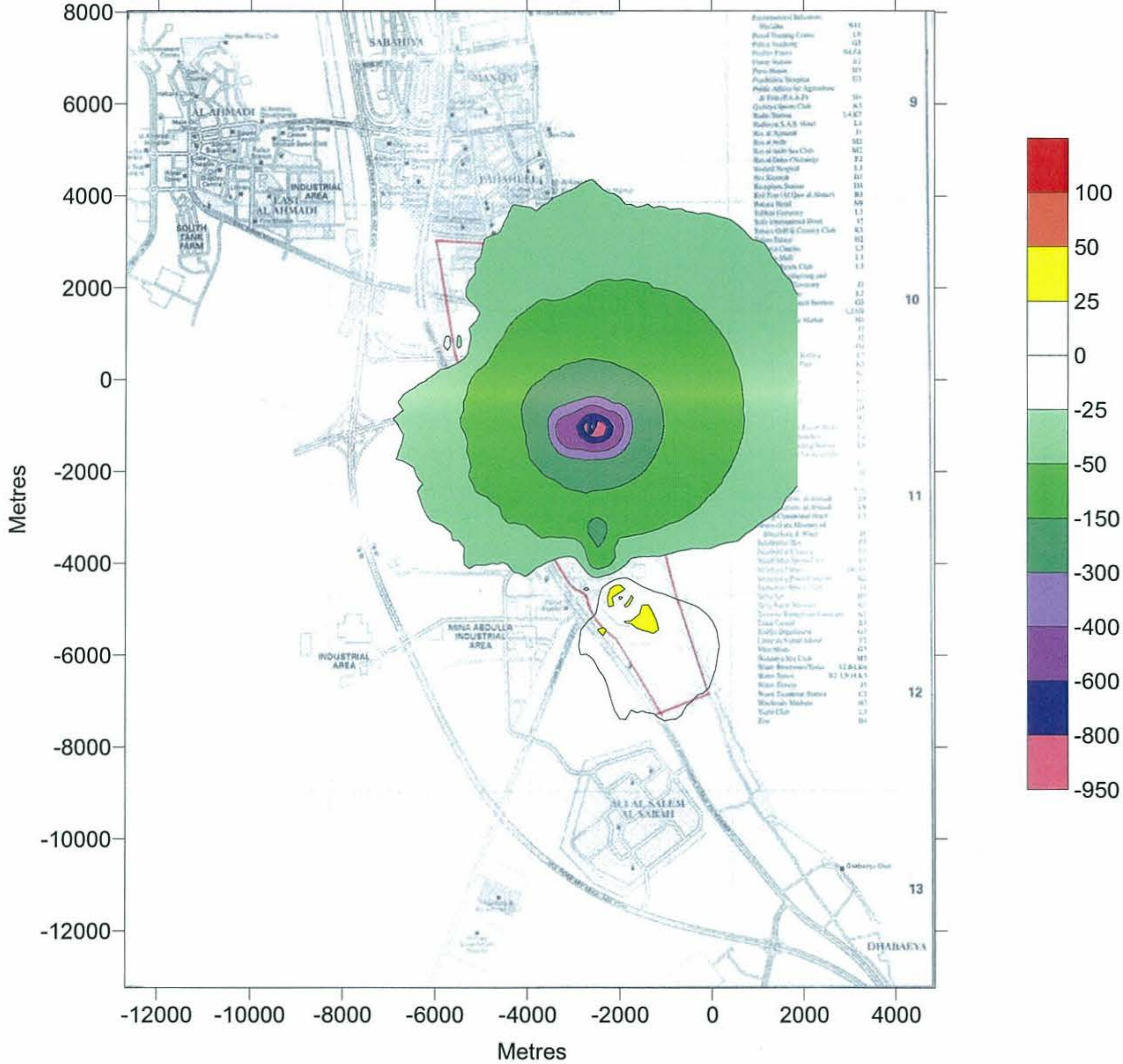
Figure 9.14: H_2S Annual Average Data (Combined - "Base Case")



Note: H_2S plot only includes the new sources installed as part of the CFP Project, as no data was available on H_2S improvements from the Decommissioned Plant.

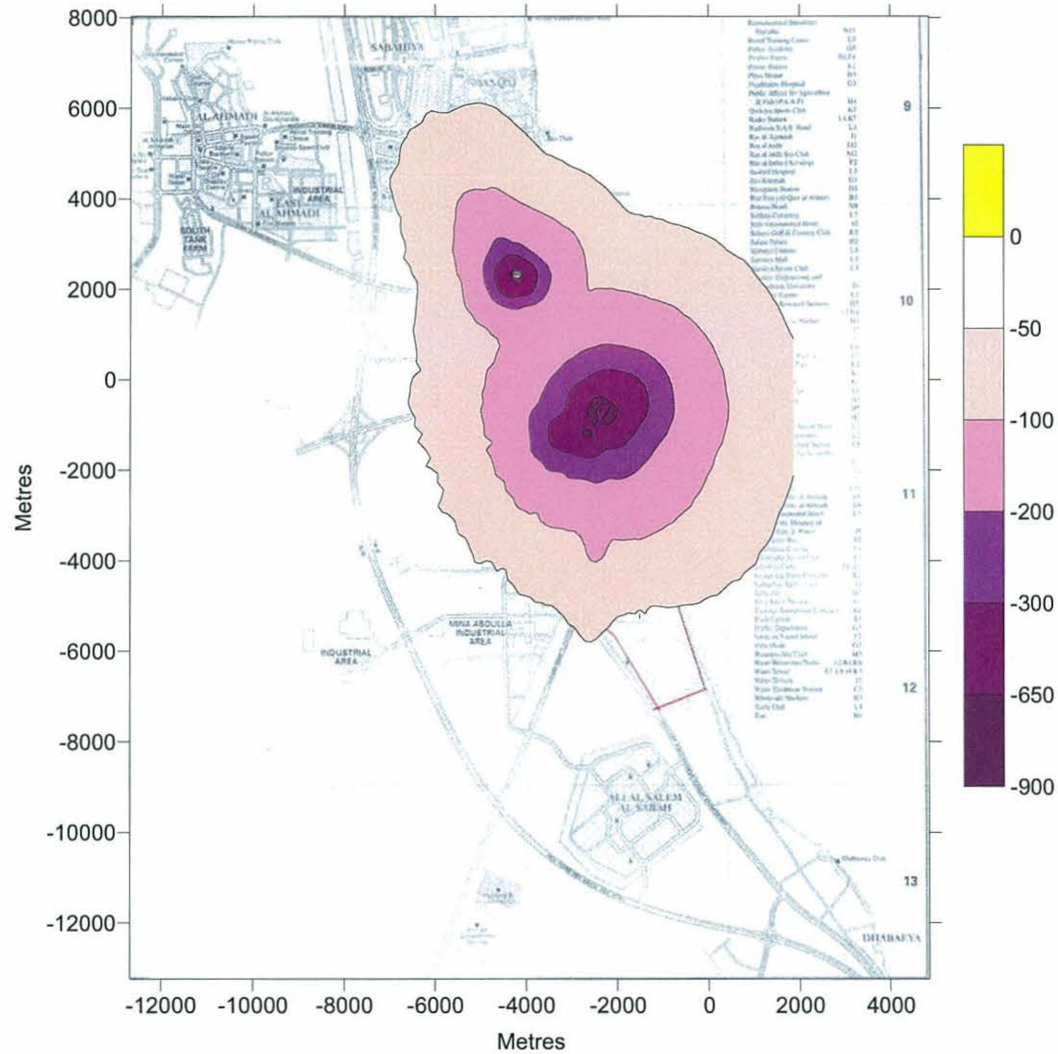
Note: The contours represent deterioration in the air quality. All results are presented in $\mu g/m^3$.

Figure 9.15: NO_x 99.7%ile 1-hour Average (Combined - "Base Case")



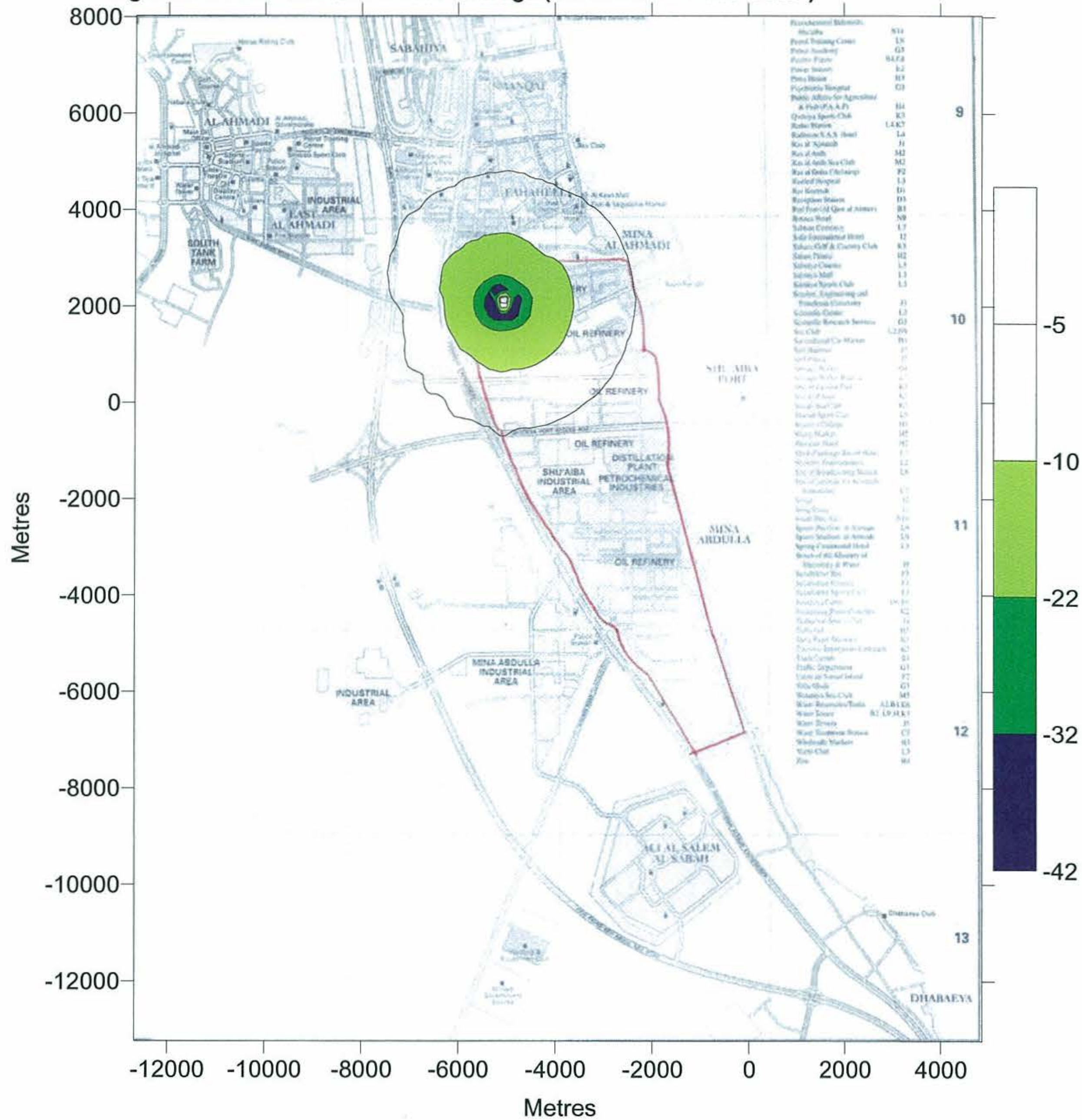
Note: The contours show both improvement and deterioration in the air quality.
All results are presented in $\mu g/m^3$.

Figure 9.16: SO_2 99.7%ile 1-hour Average (Combined - "Base Case")



Note: The contours show improvement in the air quality. All results are presented in µg/m^3.

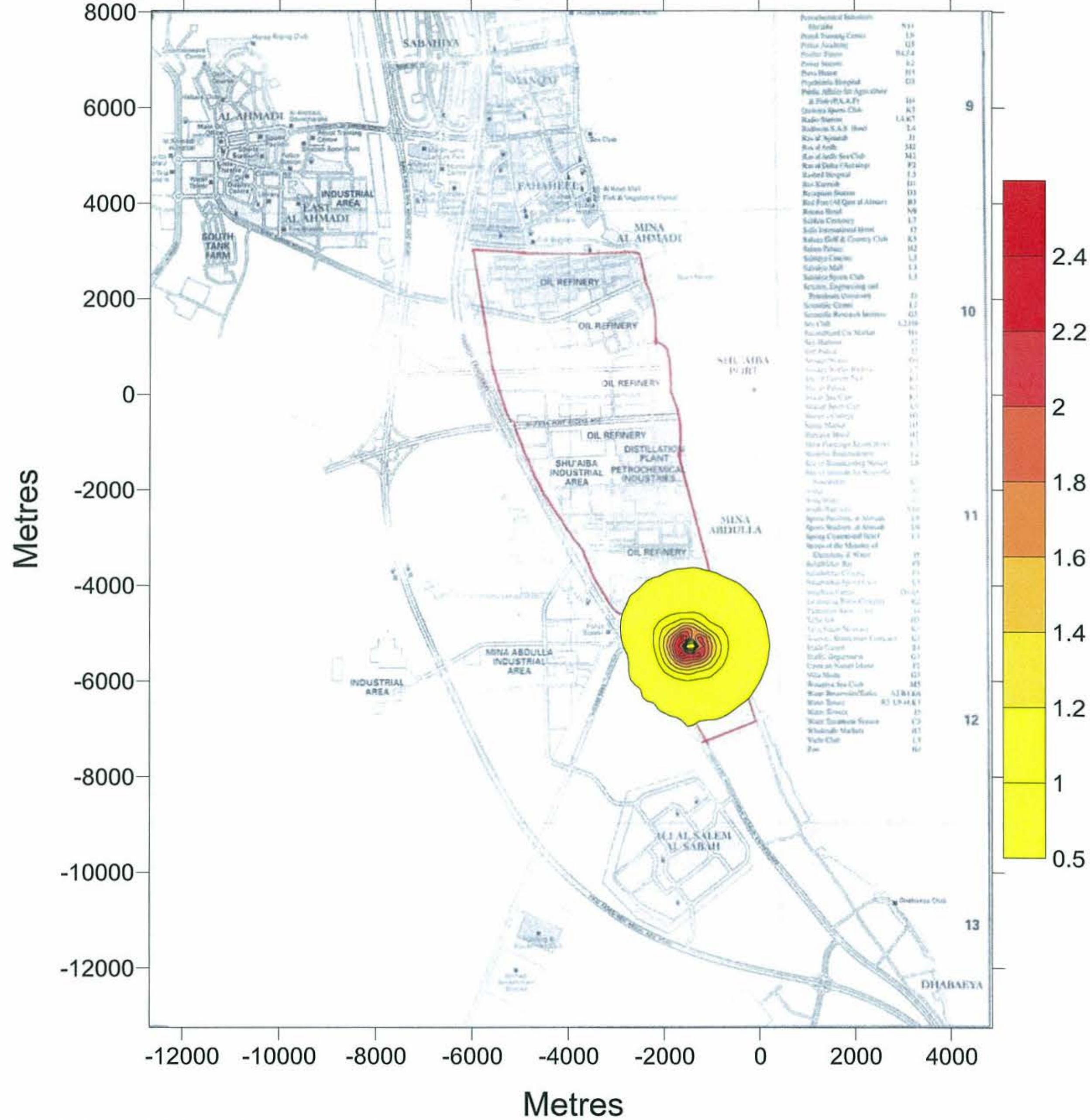
Figure 9.17: TSP 99.7%ile 1-hour Average (Combined - "Base Case")



Note: Under normal operating conditions all fired CFP equipment will use gaseous fuel which is not a significant source of particulate emissions. The new coke handling facility at MAA (Unit 187) has the potential for significant particulate emissions but it will be tightly controlled, hence there will only be an overall improvement in the TSP levels which is reflected in the above figure, as the model also incorporates the installation of an ESP at the FCCU unit at MAA.

All results are presented in $\mu g/m^3$.

Figure 9.18: H_2S 99.7%ile 1-hour Average (Combined - "Base Case")



Note: H_2S plot only includes the new sources installed as part of the CFP Project, as no data was available on H_2S improvements from the Decommissioned Plant.

Note: The contours represent deterioration in the air quality. All results are presented in $\mu g/m^3$.

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From the results presented in the above figures, it can be seen that air quality is significantly improved especially at SHU and areas in its immediate vicinity for all the pollutants considered. This excludes H_2S as no data were available for emissions from sources that are to be decommissioned.

As mentioned previously, the contour results presented do not include the background concentration data for the various monitoring point locations. In order to make a comprehensive comparison against the relevant criteria of the resulting air quality in the area after the CFP project has been completed, the predicted ADMS concentrations at these locations are combined with the background concentrations presented in Table 9.2. The resulting concentrations at each location are then compared against the K-EPA / MOO criteria, in order to identify the areas where exceedances are observed. Furthermore, the resulting concentrations were compared to the actual background data concentrations at each location in order to identify the overall impact of the CFP project on the air quality (i.e. whether the air quality has generally improved or not at these specific points).

Table 9.17 summarises the various pollutant concentrations at all the monitoring point locations. Note that the NO_2 concentrations correspond to 10% of the predicted ADMS NO_x concentrations.

Table 9.17: Pollutant Concentrations at Monitoring Points for "Base Case" Post-CFP, including existing Baseline Data.

Monitoring Point	Annual Average (µg/m³)					99.7%ile 1-hour average (µg/m³)				
	NO2	SO2	H2S	CO*	TSP	NO2	SO2	H2S	CO	TSP
A1	19.9	20.6	6.0	N/A	569.4	22.8	0.0	7.6	0.0	621.0
A2	13.0	32.8	5.0	N/A	278.6	17.0	0.0	6.4	0.0	294.0
A3	12.9	11.1	5.8	N/A	179.6	12.9	0.0	7.3	0.0	193.8
A4	15.1	11.2	5.7	N/A	604.8	16.4	0.0	7.2	0.0	669.2
A5	15.5	14.4	5.7	N/A	N/A	18.1	0.0	7.2	0.0	N/A
A6	21.2	27.5	5.7	N/A	289.4	25.0	0.0	7.2	0.0	311.6
A7	11.5	28.6	5.5	N/A	N/A	14.6	3.3	6.9	0.0	N/A
A8	14.7	80.4	8.4	N/A	214.3	9.7	0.0	10.6	0.0	233.2
A9	14.6	35.1	8.0	N/A	174.0	17.7	0.0	10.2	0.0	184.1
A10	16.5	19.5	4.4	N/A	N/A	19.6	0.0	5.5	0.0	N/A
A11	14.0	21.1	5.2	N/A	N/A	16.7	1.2	6.6	0.0	N/A
A12	19.5	19.8	5.8	N/A	N/A	23.4	0.0	7.3	0.0	N/A
A13	13.0	34.8	4.3	N/A	193.8	16.5	0.0	5.5	0.0	200.0
A14	15.1	16.0	9.8	N/A	1009.7	0.0	0.0	12.4	0.0	1118.5
A15	15.5	11.5	5.9	N/A	N/A	18.2	0.0	7.4	0.0	N/A
A16	14.8	14.9	6.9	N/A	389.6	17.6	0.0	8.7	0.0	427.7
A17	10.1	23.5	4.3	N/A	N/A	12.7	22.0	5.4	0.0	N/A
A18	8.5	20.3	5.7	N/A	N/A	10.8	11.9	7.2	0.0	N/A
A19	0.0	0.0	8.1	N/A	189.8	0.0	0.0	10.2	0.0	209.2
A20	16.1	35.4	6.9	N/A	164.5	18.9	0.0	8.8	0.0	177.0
A21	19.0	80.2	7.4	N/A	719.9	24.9	68.9	10.2	0.0	798.2
A22	10.4	30.7	6.1	N/A	N/A	10.9	0.0	7.7	0.0	N/A
A23	19.7	78.7	10.7	N/A	429.9	24.1	57.3	14.1	0.0	476.2
A24	20.5	78.9	7.0	N/A	329.9	26.9	76.4	9.9	0.0	365.4

Monitoring Point	Annual Average (µg/m³)					99.7%ile 1-hour average (µg/m³)				
	NO2	SO2	H2S	CO*	TSP	NO2	SO2	H2S	CO	TSP
A25	9.8	28.7	5.8	N/A	N/A	11.9	24.4	7.3	0.0	N/A
A26	11.7	41.2	7.4	N/A	N/A	14.8	36.4	9.6	0.0	N/A
A27	15.7	31.2	6.8	N/A	1102.9	22.9	16.8	9.0	0.0	1222.3
A28	10.2	22.5	0.0	N/A	N/A	13.0	23.7	0.0	0.0	N/A
A29	14.5	36.7	6.3	N/A	285.9	17.6	0.0	8.4	0.0	317.1
A30	17.0	66.2	6.6	N/A	459.9	22.0	63.7	8.8	0.0	509.8
A31	15.0	34.2	6.9	N/A	N/A	19.8	27.4	8.8	0.0	N/A
A32	10.5	30.6	7.2	N/A	N/A	11.8	10.4	9.1	0.0	N/A
A33	12.7	40.4	8.0	N/A	214.9	16.8	22.5	10.7	0.0	238.1
A34	5.8	9.2	14.5	N/A	N/A	5.8	0.0	18.2	0.0	N/A
A35	10.6	27.7	8.7	N/A	N/A	13.8	19.1	11.1	0.0	N/A
A36	9.9	33.7	6.7	N/A	N/A	10.9	15.3	8.4	0.0	N/A
A37	15.4	44.7	9.9	N/A	699.7	0.0	0.0	12.5	0.0	774.7
A38	13.1	85.0	9.6	N/A	204.8	0.0	0.0	12.1	0.0	226.5
A39	16.7	37.4	7.3	N/A	719.9	17.7	0.0	9.3	0.0	798.7
A40	15.6	33.1	6.7	N/A	N/A	14.2	0.0	8.5	0.0	N/A
A41	9.9	33.2	6.6	N/A	994.8	7.9	0.0	8.3	0.0	1101.7
A42	13.1	36.3	6.1	N/A	219.7	6.8	0.0	7.7	0.0	242.0
A43	11.5	28.2	7.6	N/A	N/A	1.0	0.0	9.6	0.0	N/A
A44	16.0	35.3	7.5	N/A	N/A	18.4	15.7	9.4	0.0	N/A
A45	6.5	24.4	4.8	N/A	N/A	6.5	2.0	6.0	0.0	N/A
KNPC C	144.1	0.0	16.0	N/A	1046.1	219.6	0.0	132.9	5656.6	3555.0
KNPC D	41.4	25.3	24.7	N/A	316.6	23.1	0.0	57.4	0	1385.3
KNPC F	69.0	12.9	5.4	N/A	525.8	181.6	82.7	29.5	2933.6	2011.0
KNPC H	53.5	27.1	3.7	N/A	201.4	94.2	38.0	13.5	0	589.2

Notes:

1. CO concentrations do not include background data (only for KNPC C and F).
2. A concentration of 0 indicates that the predicted cumulative concentration is negative.

* Long term (i.e. annual) concentrations are not applicable for CO.

The above predicted concentrations at each monitoring point, after the completion of the CFP project, were compared against the applicable criteria. Table 9.18, illustrates the ratios of the predicted concentration (including existing baseline) against the relevant criterion, with exceedances highlighted in red font. Furthermore, for the monitoring points where exceedances are observed, the way the pollutant concentration has changed, compared to the background data information, after completion of the CFP is also indicated ("✓" indicates improvement in air quality, "×" deterioration in air quality, and "-" no change in air quality).

Finally, in order to summarise the overall contribution of the CFP project, the background concentrations at each monitoring point (see Table 9.2) were compared to the predicted concentrations after the CFP completion (the "Base Case"). Table 9.19 summarises the changes in the various pollutant concentrations at each monitoring point.

Table 9.18: Exceedances of Criteria for Ambient Air Quality for "Base Case" Post-CFP, including existing Baseline Data.

Averaging Period	Annual					99.7%ile 1-hour Average					99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)										Ratio against Industrial Criteria
Monitoring Location	NO2	SO2	H2S#	CO*	TSP	NO2	SO2	H2S#	CO	TSP	SO2
A1	0.3	0.3	0.8	-	7.6 (✓)	0.1	0.0	0.2	0.0	2.0 (✓)	0.0
A2	0.2	0.4	0.6	-	3.7 (✓)	0.1	0.0	0.2	0.0	0.9	0.0
A3	0.2	0.1	0.7	-	2.4 (✓)	0.1	0.0	0.2	0.0	0.6	0.0
A4	0.2	0.1	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A5	0.2	0.2	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A6	0.3	0.3	0.7	-	3.9 (✓)	0.1	0.0	0.2	0.0	1.0 (✓)	0.0
A7	0.2	0.4	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A8	0.2	1.0(✓)	1.1	-	2.9 (✓)	0.0	0.0	0.3	0.0	0.7	0.0
A9	0.2	0.4	1.0	-	2.3 (✓)	0.1	0.0	0.3	0.0	0.6	0.0
A10	0.2	0.2	0.6	-	N/A	0.1	0.0	0.1	0.0	N/A	0.0
A11	0.2	0.3	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A12	0.3	0.2	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A13	0.2	0.4	0.5	-	2.6 (✓)	0.1	0.0	0.1	0.0	0.6	0.0
A14	0.2	0.2	1.2	-	13.5 (✓)	0.0	0.0	0.3	0.0	3.5 (✓)	0.1
A15	0.2	0.1	0.7	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A16	0.2	0.2	0.9	-	5.2 (✓)	0.1	0.0	0.2	0.0	1.3 (✓)	0.1
A17	0.2	0.3	0.5	-	N/A	0.1	0.0	0.1	0.0	N/A	0.1
A18	0.1	0.3	0.7	-	N/A	0.0	0.0	0.2	0.0	N/A	0.0
A19	0.0	.0.0	1.0	-	2.5 (✓)	0.0	0.0	0.3	0.0	0.7	0.0
A20	0.2	0.4	0.9	-	2.2 (✓)	0.1	0.0	0.2	0.0	0.6	0.0
A21	0.3	1.0(✓)	0.9	-	9.6 (✓)	0.1	0.2	0.3	0.0	2.5 (✓)	0.0
A22	0.2	0.4	0.8	-	N/A	0.0	0.0	0.2	0.0	N/A	0.0
A23	0.3	1.0(✓)	1.3	-	5.7 (✓)	0.1	0.1	0.4	0.0	1.5 (✓)	0.0
A24	0.3	1.0(-)	0.9	-	4.4 (✓)	0.1	0.2	0.2	0.0	1.2 (✓)	0.1
A25	0.1	0.4	0.7	-	N/A	0.1	0.1	0.2	0.0	N/A	0.0
A26	0.2	0.5	0.9	-	N/A	0.1	0.1	0.2	0.0	N/A	0.0
A27	0.2	0.4	0.9	-	14.7 (✓)	0.1	0.0	0.2	0.0	3.9 (✓)	0.0
A28	0.2	0.3	0.0	-	N/A	0.1	0.1	0.0	0.0	N/A	0.0
A29	0.2	0.5	0.8	-	3.8 (✓)	0.1	0.0	0.2	0.0	1.0	0.0
A30	0.3	0.8	0.8	-	6.1 (✓)	0.1	0.1	0.2	0.0	1.6 (✓)	0.0
A31	0.2	0.4	0.9	-	N/A	0.1	0.1	0.2	0.0	N/A	0.0
A32	0.2	0.4	0.9	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A33	0.2	0.5	1.0	-	2.9	0.1	0.1	0.3	0.0	0.8	0.0
A34	0.1	0.1	1.8	-	N/A	0.0	0.0	0.5	0.0	N/A	0.0
A35	0.2	0.3	1.1	-	N/A	0.1	0.0	0.3	0.0	N/A	0.0
A36	0.1	0.4	0.8	-	N/A	0.0	0.0	0.2	0.0	N/A	0.0
A37	0.2	0.6	1.2	-	9.3 (✓)	0.0	0.0	0.3	0.0	2.4 (✓)	0.0
A38	0.2	1.1(✓)	1.2	-	2.7 (✓)	0.0	0.0	0.3	0.0	0.7	0.0

Averaging Period	Annual					99.7%ile 1-hour Average					99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)										Ratio against Industrial Criteria
Monitoring Location	**NO2**	**SO2**	**H2S#**	**CO***	**TSP**	**NO2**	**SO2**	**H2S#**	**CO**	**TSP**	**SO2**
A39	0.2	0.5	0.9	-	9.6 (✓)	0.1	0.0	0.2	0.0	2.5 (✓)	0.0
A40	0.2	0.4	0.8	-	8.1 (✓)	0.1	0.0	0.2	0.0	2.1 (✓)	0.0
A41	0.1	0.4	0.8	-	N/A	0.0	0.0	0.2	0.0	N/A	0.0
A42	0.2	0.5	0.8	-	13.3 (✓)	0.0	0.0	0.2	0.0	3.5 (✓)	0.0
A43	0.2	0.4	1.0	-	2.9 (✓)	0.0	0.0	0.2	0.0	0.8	0.0
A44	0.2	0.4	0.9	-	N/A	0.1	0.0	0.2	0.0	N/A	0.0
A45	0.1	0.3	0.6	-	N/A	0.0	0.0	0.2	0.0	N/A	0.0
KNPC C	2.2(✓)	0.0	2.0	-	13.9 (✓)	1.0(✓)	0.0	3.3	0.2	11.2 (✓)	0.0
KNPC D	0.6	0.3	3.1	-	4.2 (✓)	0.1	0.0	1.4	0.0	4.4 (✓)	0.0
KNPC F	1.0(-)	0.2	0.7	-	7.0 (✓)	0.8	0.2	0.7	0.1	6.3 (✓)	0.1
KNPC H	0.8	0.3	0.5	-	2.7 (✓)	0.4	0.1	0.3	0.0	1.9 (✓)	0.0

Note: All negative ratios have been rounded to 0.

Key: Red highlighted cells indicate exceedance against K-EPA / MOO criteria.

✓: Pollutant Concentration reduced after CFP Project Completion.

×: Pollutant Concentration increased after CFP Project Completion.

- : Pollutant Concentration not changed after CFP Project Completion.

N/A: Not Applicable

* Long term (i.e. annual) concentrations are not applicable for CO.

No hydrogen sulphide emission data were available for decommissioned units, hence determination whether resulting H2S concentrations have got worse or better cannot be made.

Table 9.19: Changes in Monitoring Point Concentrations ("Base Case") Post-CFP, including existing Baseline Data.

Monitoring Point	Annual Average Concentrations					99.7%ile 1-hour average Concentrations				
	NO2	**SO2**	**H2S**	**CO**	**TSP**	**NO2**	**SO2**	**H2S**	**CO**	**TSP**
A1	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A2	×	✓	-	-	✓	×	✓	×	N/A	✓
A3	✓	✓	-	-	✓	✓	✓	-	N/A	✓
A4	✓	✓	×	-	N/A	✓	✓	×	N/A	×
A5	✓	✓	-	-	N/A	✓	✓	×	N/A	×
A6	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A7	✓	✓	-	-	N/A	×	✓	×	N/A	N/A
A8	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A9	×	✓	-	-	✓	✓	✓	×	N/A	✓
A10	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A
A11	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A
A12	✓	✓	-	-	N/A	✓	✓	-	N/A	N/A
A13	×	✓	-	-	✓	×	✓	×	N/A	✓
A14	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A15	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A

Monitoring Point	Annual Average Concentrations					99.7%ile 1-hour average Concentrations				
	NO2	SO2	H2S	CO	TSP	NO2	SO2	H2S	CO	TSP
A16	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A17	✓	✓	-	-	N/A	×	✓	×	N/A	N/A
A18	✓	✓	-	-	N/A	×	✓	×	N/A	N/A
A19	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A20	×	✓	-	-	✓	✓	✓	×	N/A	✓
A21	×	✓	-	-	✓	×	✓	×	N/A	✓
A22	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A
A23	✓	✓	-	-	✓	✓	✓	×	N/A	✓
A24	×	✓	×	-	✓	×	✓	×	N/A	✓
A25	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A
A26	×	✓	-	-	N/A	×	✓	×	N/A	N/A
A27	×	✓	-	-	✓	×	✓	×	N/A	✓
A28	✓	✓	-	-	N/A	×	✓	×	N/A	N/A
A29	×	✓	-	-	✓	✓	✓	×	N/A	✓
A30	×	✓	×	-	✓	×	✓	×	N/A	✓
A31	✓	✓	×	-	N/A	×	✓	×	N/A	N/A
A32	✓	✓	-	-	N/A	✓	✓	×	N/A	N/A
A33	×	✓	-	-	✓	×	✓	×	N/A	✓
A34	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A35	×	✓	×	-	N/A	×	✓	×	N/A	N/A
A36	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A37	✓	✓	×	-	✓	✓	✓	×	N/A	✓
A38	✓	✓	×	-	✓	✓	✓	×	N/A	✓
A39	✓	✓	×	-	✓	✓	✓	×	N/A	✓
A40	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A41	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A42	✓	✓	×	-	✓	✓	✓	×	N/A	✓
A43	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A44	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
A45	✓	✓	×	-	N/A	✓	✓	×	N/A	N/A
KNPC C	✓	✓	×	-	✓	✓	✓	×	✓	✓
KNPC D	✓	✓	×	-	✓	✓	✓	×	N/A	✓
KNPC F	✓	✓	-	-	✓	✓	✓	×	✓	✓
KNPC H	×	✓	-	-	✓	×	✓	×	N/A	✓

Key:	✓	Concentration reduced after CFP Project Completion
	×	Concentration increased after CFP Project Completion
	-	Concentration not changed after CFP Project Completion
	N/A	Not Applicable

As shown in Table 9.18, there remains a number of exceedances of criteria for various pollutants, after the completion of the CFP project (for normal operating conditions). It is noted here that for the case of H_2S, a direct conclusion cannot be drawn, as for the purposes of modelling no information was available for H_2S emissions from the decommissioned sources. Only H_2S emissions related to the new sources were included in the model and as seen from their resulting dispersion contours (see Figure 9.14 and Figure 9.18) the overall effect to resulting air quality is insignificant (< 0.5 $\mu g/m^3$ deterioration for short term concentrations outside the site boundary).

There is an improvement to the TSP concentrations at all locations, despite the large number of exceedances at most monitoring points. Despite the large improvement in particulate emissions because of the installation of the electrostatic precipitator on Unit 86 of MAA, the improvement on ground level concentrations is relatively small because of the large height of the installation (> 70 m).

There are a few exceedances for both short and long term NO_2 and SO_2 concentrations at various monitoring points, but an overall improvement of these is observed, compared to the existing baseline concentrations. The most serious case of exceedance for the aforementioned pollutants is observed at monitoring points KNPC C, at SHU Refinery. It can be argued that the location of this point can be considered onsite, rather than at the site boundary, given its proximity to the main CFP Block.

As indicated in Table 9.19, in the vast majority of cases the CFP project results in an overall reduction to both the long and short term concentrations of NO_2, SO_2 and TSP at the various monitoring points considered in this study. Some long and short term NO_2 concentrations are slightly increased after the completion of the CFP (e.g. at monitoring locations A2, A9, A13,A20,A21,A35,KNPC H etc), but all of these comply with the applicable K-EPA / MOO criteria.

As mentioned previously, a meaningful conclusion with regards to H_2S concentrations can not be made, as only details of new emissions have been made available at this stage for this pollutant. No information on decommissioned H_2S emissions was included in the air modelling conducted. Based on the results, only small increases in the long and short term concentrations of H_2S have been observed. The few observed exceedances are mainly due to the existing background concentrations at these monitoring points. The most serious exceedances are observed at monitoring points KNPC C and D, located at the boundary fence of SHU Refinery.

In conclusion, CFP normal operations will result in improved air quality in most of the study area. The concentrations of the various pollutants are reduced in the majority of the monitoring points considered. Exceedances will still occur, although such exceedances will be smaller than existing exceedances as a result of the CFP. In general, it can be said that there will be significant improvements in the air quality for all the monitoring point locations that currently exceed K-EPA / MOO air quality criteria.

9.4.6.2 Combined "Maximum Emission" + "Decommissioned Emission" Scenario

The approach followed for this case is similar to the "Base Case", and has been modelled as follows:

- New Maximum Emissions model (sources from Table 9.9) combined with the Decommissioned Emissions model (sources from Table 9.10) to produce the ground level concentration contours for the various pollutants

- The combined, predicted ADMS concentrations at the monitoring point locations are combined with existing baseline air quality data, in order to estimate the future air quality in the area, and then compared against the relevant K-EPA / MOO criteria.

The results for the "maximum" case are presented in the form of tables summarising the exceedances against the relevant K-EPA / MOO criteria, whilst also comparing the predicted, combined concentrations to the actual background data at each location, in order to identify the overall impact of the CFP project on the air quality.

Table 9.20 below summarises the various resulting pollutant concentrations at each monitoring point for the "maximum" case.

Table 9.20: Pollutant Concentrations at Monitoring Points for "Maximum Case" Post-CFP, including existing Baseline Data.

Monitoring Point	Annual Average (μg/m³)				99.7%ile 1-hour average (μg/m³)			
	NO2	SO2	H2S	CO*	NO2	SO2	H2S	CO
A1	20.0	21.2	6.0	N/A	23.3	0.0	7.6	0.0
A2	13.1	33.3	5.0	N/A	17.9	6.5	6.5	8.4
A3	12.9	11.5	5.8	N/A	13.2	0.0	7.4	0.0
A4	15.1	11.6	5.7	N/A	16.6	0.0	7.3	0.0
A5	15.5	14.7	5.7	N/A	18.4	0.0	7.2	0.0
A6	21.2	27.9	5.7	N/A	25.5	0.0	7.3	4.6
A7	11.5	28.8	5.5	N/A	14.9	6.2	7.0	4.2
A8	14.8	81.4	8.4	N/A	10.2	0.0	10.7	0.0
A9	14.7	36.0	8.0	N/A	18.9	0.0	10.2	10.1
A10	16.5	19.6	4.4	N/A	19.8	0.0	5.6	1.7
A11	14.0	21.3	5.2	N/A	17.0	0.0	6.6	3.7
A12	19.5	19.9	5.8	N/A	23.6	0.0	7.3	0.0
A13	13.1	35.2	4.3	N/A	17.3	0.0	5.6	9.5
A14	15.2	16.7	9.8	N/A	0.0	0.0	12.6	0.0
A15	15.5	11.6	5.9	N/A	18.3	0.0	7.5	0.0
A16	14.8	15.4	6.9	N/A	18.0	0.0	8.8	0.0
A17	10.1	23.6	4.3	N/A	12.8	23.9	5.4	3.1
A18	8.5	20.4	5.7	N/A	10.9	13.9	7.2	3.4
A19	0.0	0.0	8.1	N/A	0.0	0.0	10.5	0.0
A20	16.3	36.4	6.9	N/A	20.7	0.0	8.8	27.0
A21	19.1	83.5	7.5	N/A	25.5	99.8	12.1	46.2
A22	10.5	31.0	6.1	N/A	11.1	6.6	8.0	1.5
A23	19.8	81.3	10.8	N/A	24.6	88.5	15.5	29.7
A24	20.6	84.0	7.1	N/A	27.5	106.8	12.3	44.9
A25	9.8	29.2	5.8	N/A	12.0	28.4	7.5	3.7
A26	11.7	43.3	7.5	N/A	15.1	50.4	10.2	16.9
A27	15.8	35.2	6.9	N/A	22.9	45.4	10.2	50.9
A28	10.2	22.6	0.0	N/A	13.0	26.8	0.1	3.6
A29	14.6	41.2	6.4	N/A	17.9	25.5	9.3	38.2
A30	17.1	71.2	6.9	N/A	22.5	90.4	10.2	31.5
A31	15.0	35.0	6.9	N/A	20.0	39.9	9.2	16.6
A32	10.5	30.9	7.2	N/A	12.1	18.7	9.3	3.9
A33	12.8	45.2	8.1	N/A	17.3	44.9	12.3	31.8

Monitoring Point	Annual Average (μg/m³)				99.7%ile 1-hour average (μg/m³)			
	NO2	SO2	H2S	CO*	NO2	SO2	H2S	CO
A34	5.8	9.3	14.5	N/A	5.9	0.0	18.3	0.0
A35	10.6	28.7	8.8	N/A	14.1	30.8	11.7	13.2
A36	10.0	34.0	6.7	N/A	11.1	21.6	8.6	1.5
A37	15.5	45.4	9.9	N/A	0.0	0.0	12.7	0.0
A38	13.2	85.7	9.6	N/A	0.0	0.0	12.3	0.0
A39	16.8	38.5	7.3	N/A	18.2	0.0	9.8	3.6
A40	15.7	33.7	6.7	N/A	14.5	0.0	8.8	0.0
A41	9.9	33.6	6.6	N/A	8.3	2.0	8.5	0.0
A42	13.2	37.0	6.1	N/A	7.4	0.0	7.9	0.0
A43	11.6	28.8	7.6	N/A	1.4	0.0	9.8	0.0
A44	16.0	35.5	7.5	N/A	18.5	19.8	9.5	0.0
A45	6.5	24.6	4.8	N/A	6.7	5.0	6.1	0.0
KNPC C	144.2	0.0	16.0	N/A	219.8	0.0	133.1	5668.8
KNPC D	41.5	25.9	24.7	N/A	23.3	0.0	57.7	0.0
KNPC F	69.0	13.3	5.4	N/A	182.1	86.5	29.6	2943.7
KNPC H	53.5	31.1	3.8	N/A	94.3	66.6	14.5	47.2

Notes:

1. CO concentrations do not include background data (only for KNPC C and F).
2. A concentration of 0 indicates that the predicted cumulative concentration is negative.

* Long term (i.e. annual) concentrations are not applicable for CO.

Table 9.21 summarises the various pollutant concentrations at all the monitoring point locations against the criteria, whereas Table 9.22 indicates the difference in the concentrations of various pollutants at each monitoring case after the completion of the CFP project (for the "maximum" case). Note that the NO_2 concentrations correspond to 10% of the predicted ADMS NO_x concentrations.

Table 9.21: Exceedances of Criteria for Ambient Air Quality for "Maximum Case" Post-CFP, including existing Baseline Data.

Averaging Period	Annual				99.7%ile 1-hour Average				99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)								Ratio against Industrial Criteria
Monitoring Location	NO2	SO2	H2S#	CO*	NO2	SO2	H2S#	CO	SO2
A1	0.3	0.3	0.8	-	0.1	0.0	0.2	0.0	0.0
A2	0.2	0.4	0.6	-	0.1	0.0	0.2	0.0	0.0
A3	0.2	0.1	0.7	-	0.1	0.0	0.2	0.0	0.0
A4	0.2	0.1	0.7	-	0.1	0.0	0.2	0.0	0.0
A5	0.2	0.2	0.7	-	0.1	0.0	0.2	0.0	0.0
A6	0.3	0.3	0.7	-	0.1	0.0	0.2	0.0	0.0
A7	0.2	0.4	0.7	-	0.1	0.0	0.2	0.0	0.0
A8	0.2	1.0(✓)	1.1	-	0.0	0.0	0.3	0.0	0.0
A9	0.2	0.5	1.0	-	0.1	0.0	0.3	0.0	0.0

Averaging Period	Annual				99.7%ile 1-hour Average				99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)								Ratio against Industrial Criteria
Monitoring Location	**NO2**	**SO2**	**H2S#**	**CO***	**NO2**	**SO2**	**H2S#**	**CO**	**SO2**
A10	0.2	0.2	0.6	-	0.1	0.0	0.1	0.0	0.0
A11	0.2	0.3	0.7	-	0.1	0.0	0.2	0.0	0.0
A12	0.3	0.2	0.7	-	0.1	0.0	0.2	0.0	0.0
A13	0.2	0.4	0.5	-	0.1	0.0	0.1	0.0	0.0
A14	0.2	0.2	1.2	-	0.0	0.0	0.3	0.0	0.0
A15	0.2	0.1	0.7	-	0.1	0.0	0.2	0.0	0.0
A16	0.2	0.2	0.9	-	0.1	0.0	0.2	0.0	0.0
A17	0.2	0.3	0.5	-	0.1	0.1	0.1	0.0	0.0
A18	0.1	0.3	0.7	-	0.0	0.0	0.2	0.0	0.0
A19	0.0	0.0	1.0	-	0.0	0.0	0.3	0.0	0.0
A20	0.2	0.5	0.9	-	0.1	0.0	0.2	0.0	0.0
A21	0.3	1.0(✓)	0.9	-	0.1	0.2	0.3	0.0	0.1
A22	0.2	0.4	0.8	-	0.0	0.0	0.2	0.0	0.0
A23	0.3	1.0(✓)	1.3	-	0.1	0.2	0.4	0.0	0.1
A24	0.3	1.0(✕)	0.9	-	0.1	0.2	0.3	0.0	0.1
A25	0.1	0.4	0.7	-	0.1	0.1	0.2	0.0	0.0
A26	0.2	0.5	0.9	-	0.1	0.1	0.3	0.0	0.1
A27	0.2	0.4	0.9	-	0.1	0.1	0.3	0.0	0.1
A28	0.2	0.3	0.0	-	0.1	0.1	0.0	0.0	0.0
A29	0.2	0.5	0.8	-	0.1	0.1	0.2	0.0	0.0
A30	0.3	0.9	0.9	-	0.1	0.2	0.3	0.0	0.0
A31	0.2	0.4	0.9	-	0.1	0.1	0.2	0.0	0.1
A32	0.2	0.4	0.9	-	0.1	0.0	0.2	0.0	0.1
A33	0.2	0.6	1.0	-	0.1	0.1	0.3	0.0	0.0
A34	0.1	0.1	1.8	-	0.0	0.0	0.5	0.0	0.1
A35	0.2	0.4	1.1	-	0.1	0.1	0.3	0.0	0.0
A36	0.1	0.4	0.8	-	0.0	0.0	0.2	0.0	0.0
A37	0.2	0.6	1.2	-	0.0	0.0	0.3	0.0	0.0
A38	0.2	1.1(✓)	1.2	-	0.0	0.0	0.3	0.0	0.0
A39	0.3	0.5	0.9	-	0.1	0.0	0.2	0.0	0.0
A40	0.2	0.4	0.8	-	0.1	0.0	0.2	0.0	0.0
A41	0.1	0.4	0.8	-	0.0	0.0	0.2	0.0	0.0
A42	0.2	0.5	0.8	-	0.0	0.0	0.2	0.0	0.0
A43	0.2	0.4	1.0	-	0.0	0.0	0.2	0.0	0.0
A44	0.2	0.4	0.9	-	0.1	0.0	0.2	0.0	0.0
A45	0.1	0.3	0.6	-	0.0	0.0	0.2	0.0	0.0
KNPC C	2.2(✓)	0.0	2.0	-	1.0(✓)	0.0	3.3	0.2	0.0
KNPC D	0.6	0.3	3.1	-	0.1	0.0	1.4	0.0	0.0
KNPC F	1.0(✓)	0.2	0.7	-	0.8	0.2	0.7	0.1	0.1
KNPC H	0.8	0.4	0.5	-	0.4	0.1	0.4	0.0	0.1

Note: All negative values have been rounded to 0.

Key: Red highlighted cells indicate exceedance against K-EPA / MOO criteria.

Averaging Period	Annual				99.7%ile 1-hour Average				99.7%ile 1-hour Average
	Ratio against Residential & Industrial Criteria (only Residential for SO2)								Ratio against Industrial Criteria
Monitoring Location	NO2	SO2	H2S#	CO*	NO2	SO2	H2S#	CO	SO2

✓: Pollutant Concentration reduced after CFP Project Completion.

×: Pollutant Concentration increased after CFP Project Completion.

- : Pollutant Concentration not changed after CFP Project Completion.

* Long term (i.e. annual) concentrations are not applicable for CO.

No hydrogen sulphide emission data were available for the decommissioned units, hence a comparison cannot be made.

Table 9.22: Change in Monitoring Point Concentrations ("Maximum Case") Post-CFP, including existing Baseline Data.

Monitoring Point	Annual Average Concentrations				99.7%ile 1-hour average Concentrations			
	NO2	SO2	H2S	CO*	NO2	SO2	H2S	CO
A1	✓	✓	-	-	✓	✓	×	N/A
A2	×	✓	-	-	×	✓	×	N/A
A3	✓	✓	-	-	✓	✓	×	N/A
A4	✓	✓	-	-	✓	✓	×	N/A
A5	✓	✓	-	-	✓	✓	×	N/A
A6	✓	✓	-	-	✓	✓	×	N/A
A7	×	✓	-	-	×	✓	×	N/A
A8	✓	✓	-	-	✓	✓	×	N/A
A9	×	✓	-	-	×	✓	×	N/A
A10	✓	✓	-	-	✓	✓	×	N/A
A11	✓	✓	-	-	✓	✓	×	N/A
A12	✓	✓	-	-	✓	✓	×	N/A
A13	×	✓	-	-	×	✓	×	N/A
A14	✓	✓	-	-	✓	✓	×	N/A
A15	✓	✓	-	-	✓	✓	×	N/A
A16	✓	✓	-	-	✓	✓	×	N/A
A17	✓	✓	-	-	×	✓	×	N/A
A18	✓	✓	-	-	×	✓	×	N/A
A19	✓	✓	-	-	✓	✓	×	N/A
A20	×	✓	-	-	×	✓	×	N/A
A21	×	✓	×	-	×	✓	×	N/A
A22	✓	✓	-	-	✓	✓	×	N/A
A23	✓	✓	-	-	✓	✓	×	N/A
A24	×	×	×	-	×	×	×	N/A
A25	✓	✓	-	-	✓	✓	×	N/A
A26	×	×	×	-	×	✓	×	N/A
A27	×	×	×	-	×	×	×	N/A
A28	×	✓	-	-	×	✓	×	N/A
A29	×	×	×	-	×	✓	×	N/A
A30	×	×	×	-	×	×	×	N/A
A31	×	✓	-	-	×	✓	×	N/A
A32	✓	✓	-	-	✓	✓	×	N/A

	Annual Average Concentrations				99.7%ile 1-hour average Concentrations			
Monitoring Point	NO2	SO2	H2S	CO*	NO2	SO2	H2S	CO
A33	×	×	×	-	×	✓	×	N/A
A34	✓	✓	-	-	✓	✓	×	N/A
A35	×	✓	×	-	×	✓	×	N/A
A36	✓	✓	-	-	✓	✓	×	N/A
A37	✓	✓	-	-	✓	✓	×	N/A
A38	✓	✓	-	-	✓	✓	×	N/A
A39	✓	✓	-	-	✓	✓	×	N/A
A40	✓	✓	-	-	✓	✓	×	N/A
A41	✓	✓	-	-	✓	✓	×	N/A
A42	✓	✓	-	-	✓	✓	×	N/A
A43	✓	✓	-	-	✓	✓	×	N/A
A44	✓	✓	-	-	✓	✓	×	N/A
A45	✓	✓	-	-	✓	✓	×	N/A
KNPC C	✓	✓	-	-	✓	✓	×	✓
KNPC D	✓	✓	-	-	✓	✓	×	N/A
KNPC F	✓	✓	-	-	✓	✓	×	✓
KNPC H	×	×	×	-	×	✓	×	N/A

Key:
✓ Concentration reduced after CFP Project Completion
× Concentration increased after CFP Project Completion
- Concentration not changed after CFP Project Completion

* Long term (i.e. annual) concentrations are not applicable for CO.

As shown in Table 9.21, there are a number of exceedances of criteria for NO_2, SO_2 and H_2S, after the completion of the CFP project (for maximum operating conditions). It is noted here that for the case of H_2S, as for the "Normal Emission" scenario, a direct conclusion cannot be drawn, as for the purposes of modelling no information was available for H_2S emissions from the decommissioned sources, and as before, H_2S impact due to new CFP sources is insignificant.

There are a few exceedances when compared to K-EPA/ MOO criteria for both short and long term NO_2 and SO_2 concentrations at various monitoring points, but an overall improvement of these is observed, compared to what the concentrations were prior to CFP completion. The exception to this is monitoring point A24, which is located at the MAB adjacent coastal area, where a slight increase in the long term sulphur dioxide concentration is observed (around 2 $\mu g/m^3$). The largest exceedance for NO_2 is observed at monitoring point KNPC C at SHU Refinery, but the implementation of the CFP improves the current situation. Also, it can be argued that the location of this point can be considered onsite, rather than at the site boundary, given its proximity to the main CFP Block.

As indicated in Table 9.22, in the majority of locations, the CFP project results in an overall improvement for both the long and short term concentrations of NO_2 and SO_2 at the various monitoring points as compared to baseline data. Some long and short term NO_2 and SO_2 concentrations have increased after the completion of the CFP (e.g. at monitoring locations A2, A7, A24,A26,A27,A29,A30,A33, and KNPC H etc), but all of them comply with the applicable K-EPA / MOO criteria. Note that the