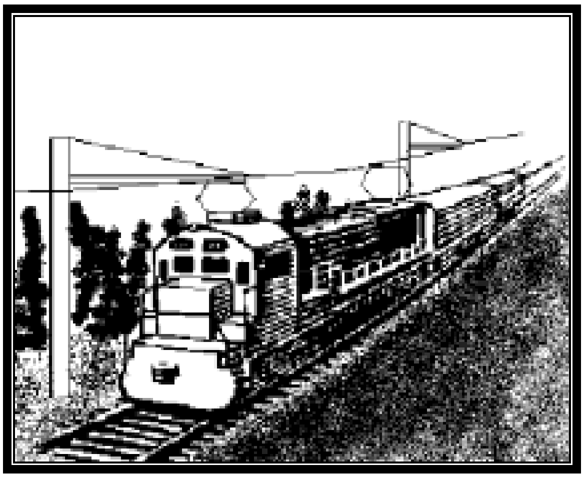
Air Pollution Associated with the Construction of Swedish Railways

Norrbotniabanan Case Study



Ross Phillips
Banverket Norra Banregionen
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Summary

The construction and operation of the Norrbotniabanan, a 270km railway to connect Umeå and Luleå, will have acutely negative impacts on local air quality in the short term but in the long term will realize significant reductions in air pollution resulting from the transportation system operating in Northern Sweden.

The following report investigates the influence of the construction on the air quality of Norrland: The emissions directly related to the construction of railways during the completion of the foundation work, superstructure and track laying, signal and telephone lining, and electrical lining are described in detail. The emissions generated by the transportation of material inputs to the construction site are also estimated. The long-term importance of construction emissions has been investigated by discerning the time required to realize their arbitrary recovery through the changes to the transportation system resulting from operation is described. According to currently available information, the emissions of NOx and CO_2 associated with construction will be recovered within 12 and seven years of operation respectively. The overall balance of air pollution over the lifecycle establishes the overall environmental benefit of the construction and operation of the Norrbotniabanan.

As the foundation work has been found to generate considerably higher air pollution emissions than the other construction phases, the machinery activity during this period modelled to determine the peak emissions rate that was then compared to environmental quality norms. The influence of the construction emissions on the air quality in the urban communities along the railway course is modelled and evaluated with reference to Sweden's environmental quality standards and objectives.

Sammanfattning

Byggandet och driften av Norrbotniabanan, en 270km långd järnväg mellan Umeå och Luleå, kommer att ha negativ påverkan på luftkvaliteten (lokalt) på kort sikt. På lång sikt kan dock luftföroreningarna från transporter att minska i norra Sverige som en följd av Norrbotniabanan.

Emissionerna från byggandet av järnvägen, dvs terrasseringen, bananunderbyggnaden, bananöverbyggnaden, signalanläggningen, telefonanläggningen och elkraftanläggningen är beskrivna i detalj. Emissionerna från transporterna av byggmaterial till byggarbetsplatserna har också uppskattas. Betydelsen av emissionerna från byggskedet har undersökts genom att jämföra dem med den förväntade minskningen i driftskedet. Enligt de beräkningar som gjorts kommer emissionerna av NOx och CO_2 att ”tjänas in” på tolv respektive sju år. Totalt sett är byggandet av Norrbotniabanan föredelaktigt ur luftföreningssynpunkt.

Terrassering är det arbetsmoment som genererar mest emissioner. En modell av maskinanvändandet under byggtiden har tagits fram för att kunna beskriva när emissionerna är som störst. Informationen om utsläppen under byggtiden har använts för att modellera påverkan på luftkvaliteten i omgivningen. De beräknade nivåerna av luftföroreningar har jämförts med Naturvårdsverkets miljökvalitetsnormer.

The modelling of NOx, HC, PM10 and CO has established that the construction activities will not adversely influence the air quality of Luleå, Skellefteå and Piteå to the extent that Naturvårdsverket's standards for air quality will be approached or exceeded.

The content of this report is directly focused on the Norrbotniabanan. However, the methodology and base calculations used in the completion of this case study may be useful in future analysis of Norrbotniabanan and other railways. The information included in this report will be a strong foundation for the completion of a lifecycle analysis of all components and activities associated with a Swedish railway. Much of the information used as the basis of this analysis is set to be revised in the impending planning stages of the Norrbotniabanan and should be revised when more recent information becomes available.

Although the construction of the Norrbotniabanan will emit pollution primarily associated with the combustion of fossil fuels by heavy machinery, these emissions will not be emitted in an intensity that will jeopardize human health or the environmental integrity of Northern Sweden. However, air pollution will be generated by the construction activities and all reasonable measures including eco-driving techniques and regulating the construction intensity should be implemented to further reduce to the lowest levels possible.

Beräkningarna av kväveoxid, kolväten, partiklar och kolmonoxid har visat att emissionerna från byggskedet inte kommer att påverka luftkvaliteten i Luleå, Piteå eller Skellefteå i en sådan utsträckning att Naturvårdsverkets miljökvalitetsnormer överskrids.

Denna rapport är en fallstudie av Norrbotniabanan men metodiken och beräkningarna kan dock användas i andra projekt. Denna studie kan användas som en del i att göra en komplett livscyckelanalys för alla komponenter och aktiviteter som ingår i byggande av järnväg. En hel del av de data som använts i studien kommer att förbättras i kommande skeden av planeringsprocessen för Norrbotniabanan. Resultaten av denna studie kommer att uppdateras efterhand.

Även om byggandet av Norrbotniabanan kommer att ge upphov till ökade luftföreningar i byggandet, främst koldioxid från fossila bränslen, kommer det inte att ske i en sådan omfattning att det innebär en risk för människors hälsa och för miljön i norra Sverige.

Eco-driving och planering av byggarbetena är exempel på åtgärder som bör användas som verktygs för att minska emissionerna så långt det är möjligt.

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§1 Introduction and Scope

The construction of the Norrbotniabanan will result in an acute increase in the emission to air of ammonia, sulphur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, carbon dioxide, methane and particulate matter during foundation work, track laying, installation of technical infrastructure etc. However, the operation of the railway line will result in a recovery of those emissions generated during construction over a relatively short period of time and a significant reduction beyond business as usual levels over its lifespan. The following investigation will explore the degree of the emissions due to construction activities, the influence these increases may have on ambient urban air quality in the communities connected by the Norrbotniabanan: Luleå, Piteå and Skellefteå, and attempt to quantify the period of time necessary to recover the emissions generated during construction.

During construction, air pollution emissions will be generated by the combustion of fossil fuels associated with the operation of heavy machinery as well as the transportation of materials to a construction site. During the operation there will be emissions due to the use of diesel locomotives for rail yard activities and maintenance.

For the purposes of this project, the scope will be confined to direct emissions with the exception of emissions related to the transportation of construction materials. Accordingly, the indirect emissions associated with the production of the material inputs to the railway will not be considered as within the scope of this investigation. In future, it may be possible to investigate the life cycle emissions as part of an environmental product declaration as well as assign monetary values to the quantity of emissions founded on health impacts, deterioration of infrastructure etc.

The existence of the Norrbotniabanan will reduce emissions during operation by accepting freight from truck and sea transportation and person traffic from personal motor vehicle traffic. Norrbotniabanan will present a shorter line of communication between the communities along the coast of the Gulf of Bothnia than current railway alternatives and likely serve to increase numbers of passengers using trains by providing a viable and competitive alternative to automobile. The influence that the emissions of air contaminants may have on the host community has been evaluated where information describing the present baseline situation exists and in a format based on the availability of local information. Consideration has also been given to the time period in which emissions resulting from construction will have the greatest effect on air quality, represented by a peak annual average emissions rate.

Nitrogen dioxide and particulate matter will be the primary focus for comparison during the analysis of the effect of construction on urban air quality. These are the air pollutants for which there is greatest association with adverse health effects, the environmental quality standards and the greatest availability of background measurement information is currently completed in Northern Sweden.

§ 2 Methodology and Analysis

The methodologies used were a compilation of previously practised methodologies and innovations where existing methods either did not exist or insufficiently described the information required. The following section provides a brief description of the methods employed in the completion of the calculations necessary for this investigation. For the purposes of analysis, the values of HC, VOC are considered comparable in certain circumstances. The emissions factors draw on information and methodologies presented in CORINAIR 2003, Persson and Kindbom, 1999, and Flodström et al. 2004.

§2.1 Emissions Factors

The emissions of air pollutant levels on a mass per time basis that are projected to result from the construction of the railway were created using the following equation (EEA, 2005).

Formula 1: Emissions

$$E = N \times HRS \times HP \times LF \times EF_i$$

Where:

E = mass of emissions of pollutant i during the inventory period
N = source population (units)
HRS = hours of use
HP = average rated motor effect
LF = typical loading factor
EF_i = average emissions of pollutant i per unit of use (e.g. g/kWh)

The emissions factors that have been adapted from the CORINAIR database for the operation of Swedish heavy machinery are presented below in Tables 3 - 6. The emissions factors below also incorporate an assumed proportion of the population using pollution control technologies (SMED, 2005).

The emissions of sulphur dioxide were estimated using the following methodology as outlined by CORINAIR and assuming that all sulphur contained in the fuel consumed is transformed to SO_2.

Formula 2: SO_2

$$E_{SO2} = 2\ \Sigma_j\ \Sigma_i\ k_{S,l}\ b_{j,l}$$

Where

$k_{S,l}$ = weight related sulphur content of fuel of type l (kg / kg)
$b_{j,l}$ = total annual consumption of fuel type 1 (kg by source category)

A sulphur fuel content of 0,001% by weight was assumed for Swedish MK1 deisel (IVL, 1999). The estimates conducted in this report assumed consumption of only MK1 diesel.

The greenhouse gas emissions estimates were prepared using the methodologies set out by CORINAIR. The ultimate CO_2 was adjusted to End of Pipe CO_2 to account for the carbon contained in fuels that was converted to CO, VOC and PM10 using the following equations (EEA, 2005).

Formula 3: Ultimate CO_2

$$\textit{Ultimate } CO_2 = 44.011(b * \delta / (12{,}011 + 1{,}008 * r_{h/c}))$$

Formula 4: End of Pipe CO_2

$$\textit{End of Pipe } CO_2 = \textit{Ultimate } CO_2 - m_{CO} / 28.011 - m_{VOC} / 13.85 - m_{PM10} / 12.011$$

Where b = fuel quantity
δ = density of fuel (gasoline = 0.7kg/L, diesel = 0.8 kg/L)
$r_{h/c}$ = ratio of hydrogen to carbon (1.8 for gasoline and 2 for diesel)
m_i = mass of pollutant i

In addition to being calculated individually, the emissions of N_2O, CH_4, and CO_2 were summed together as total greenhouse gas emissions expressed in carbon dioxide equivalents (CO_2e). The values employed for the global warming potential (GWP) of the principal greenhouse gases are listed below.

Table 1: GWP of Calculated GHG Emissions (Naturvårdsverket, 2005)

Greenhouse Gas	GWP (CO_2 e)
CO_2	1
CH_4	21
N_2O	310

The emission factors are presented on a mass per operation time (g / operation hr) or mass per power basis (g / kWh) for construction machinery used during the foundation work, track laying and installation of technical infrastructure systems such as the telephone, signal and electrical systems. As will be seen in the following tables, emissions factors for carbon dioxide and sulphur dioxide are based only on hourly operation time. These emissions are directly dependant on the fuel consumption of a vehicle, not the typical motor effect. The emissions factors based on operation time were generated by multiplying the emissions factors based on motor effect by the typical motor effect and the typical operation efficiency of the vehicle. Please see Appendix for the translation of the machinery names.

Formula 5: Emissions per Hour

$$EF_t = EF_{ME} \times P \times \eta$$

Where:

EF_t = Emission Factor per Operation Time
EF_{ME} = Emission Factor per Typical Motor Effect
P = Typical Motor Effect
η = Operating Efficiency

Table 2: Emissions Factors for Heavy Machinery Based on Motor Effect

Machine	Typical Motoreffekt	CO	NMVOC	NOx	Partiklar	N2O	CH4	NH3
	kW	(g/kWh)						
Bandlastare	110	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Bandschaktare	130	3,79	1,3	11,23	0,76	0,35	0,05	0,002
Beläggningsmaskiner	80	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Dumper, ramstydra	180	3,47	1,3	11,98	0,84	0,35	0,05	0,002
Grävlastare	70	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Grävmaskiner, band < 6.1 ton	40	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Grävmaskiner, band > 6.1 ton	150	3,47	1,3	11,98	0,84	0,35	0,05	0,002
Grävmaskiner, hjul	100	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Hjullastare*till jordbr	100	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Mobilkranar < 10 ton kapacitet	150	3,47	1,3	11,98	0,84	0,35	0,05	0,002
Mobilkranar > 10 ton kapacitet	345	3,47	1,3	11,98	0,84	0,35	0,05	0,002
Skidsteers(Kompaktlastare)	40	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Teleskoptruck	70	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Tipptruck	300	3,47	1,3	11,98	0,84	0,35	0,05	0,002
Väghyvlar	110	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Vältar	70	5,05	2,2	12,66	1,23	0,35	0,05	0,002
Truck	80	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Borraggr. Entrepr	100	4,25	1,52	11,23	0,88	0,35	0,05	0,002
Stenkrossar	225	3,47	1,3	11,98	0,84	0,35	0,05	0,002

Table 3: Emissions Factors for Heavy Machinery Based on Operation Time

Machine	CO	NMVOC	Nox	Partiklar	N2O	CH4	NH3	CO2	SO2
	g/h							kg/h	g/h
Bandlastare	233,74	83,81	617,74	48,52	19,25	2,75	0,11	37,63	0,024
Bandschaktare	246,35	84,50	730,06	49,43	22,75	3,25	0,13	45,16	0,0288
Beläggningsmaskiner	161,75	70,26	405,16	39,42	11,20	1,60	0,064	10,03	0,0064
Dumper, ramstydra	250,13	93,60	862,49	60,21	25,20	3,60	0,144	50,18	0,032
Grävlastare	141,54	61,48	354,52	34,49	9,80	1,40	0,056	30,11	0,0192
Grävmaskiner, band < 6.1 ton	80,88	35,13	202,58	19,71	5,60	0,80	0,032	25,09	0,016
Grävmaskiner, band > 6.1 ton	208,44	78,00	718,74	50,17	21,00	3,00	0,12	45,16	0,0288
Grävmaskiner, hjul	191,24	68,57	505,42	39,70	15,75	2,25	0,09	45,17	0,0288
Hjullastare*till jordbr	233,74	83,81	617,74	48,52	19,25	2,75	0,11	50,18	0,032
Mobilkranar < 10 ton kapacitet	260,55	97,50	898,42	62,72	26,25	3,75	0,15	35,12	0,0224
Mobilkranar > 10 ton kapacitet	359,56	134,55	1 239,83	86,55	36,23	5,18	0,207	35,11	0,0224
Skidsteers(Kompaktlastare)	60,66	26,35	151,94	14,78	4,20	0,60	0,024	30,12	0,0192
Teleskoptruck	141,54	61,48	354,52	34,49	9,80	1,40	0,056	10,03	0,0064
Tipptruck	364,77	136,50	1 257,79	87,81	36,75	5,25	0,21	50,17	0,032
Väghyvlar	233,74	83,81	617,74	48,52	19,25	2,75	0,11	42,65	0,0272
Vältar	141,54	61,48	354,52	34,49	9,80	1,40	0,056	10,03	0,0064
Truck	102,00	36,57	269,56	21,17	8,40	1,20	0,048	27,60	0,0176
Borragr. Entr.	382,48	137,15	1 010,85	79,40	31,50	4,50	0,18	50,17	0,032
Stenkrossar	625,32	234,00	2 156,22	150,52	63,00	9,00	0,36	112,90	0,072

Table 4: Emissions Factors for Heavy Track Bound Machinery Based on Motor Effect

Banverket Machines	Motor Effect	CO	NMVOC	NOx	Partiklar	N2O	CH4	NH3
	kW	g/kWh						
Dieselarbetslok Banverket	130 - 560	3,200	1,170	12,627	0,902	0,350	0,050	0,002
Diesellinjelok Banverket	> 560	3,000	1,300	13,100	0,950	0,350	0,050	0,002
Övrigt Banverket	20 - 37	6,392	2,868	12,962	1,547	0,350	0,050	0,002
Övrigt Banverket	37 - 75	5,055	2,196	13,100	1,344	0,350	0,050	0,002
Övrigt Banverket	75 - 130	4,250	1,524	11,232	0,882	0,350	0,050	0,002
Övrigt Banverket	130 - 560	3,474	1,300	11,979	0,836	0,350	0,050	0,002
Övrigt Banverket	> 560	3,000	1,300	13,100	0,950	0,350	0,050	0,002

Table 5: Emissions Factors for Heavy Track Bound Machinery Based on Operation Time

Banverket Machines	Motor Effect	CO	NMVOC	NOx	Partiklar	N2O	CH4	NH3	SO2	CO2
	kW	g/h								kg/h
Dieselarbetslok Banverket	130 - 560	230,40	84,24	909,14	64,94	25,20	3,60	0,14	0,02	17,68
Diesellinjelok Banverket	> 560	783,00	339,30	3 419,10	247,95	91,35	13,05	0,52	0,09	69,04
Övrigt Banverket	20 - 37	28,77	12,90	58,33	6,96	1,58	0,23	0,01	0,01	10,00
Övrigt Banverket	37 - 75	84,92	36,89	220,08	22,59	5,88	0,84	0,03	0,01	7,42
Övrigt Banverket	75 - 130	137,69	49,37	363,91	28,58	11,34	1,62	0,06	0,01	11,61
Övrigt Banverket	130 - 560	212,61	79,56	733,11	51,18	21,42	3,06	0,12	0,02	12,30
Övrigt Banverket	> 560	577,50	250,25	2 521,75	182,88	67,38	9,63	0,39	0,09	88,47

§2.2 Calculation of Total Emissions

In order to properly represent the cumulative emissions resulting from the construction of the Norrbotniabanan, the emissions were divided into different phases in order to ease and rationalize the calculation of air pollution. The emissions were divided into the categories of 1. The foundation-work (terracing) and ballast laying. 2. The laying of tracks, slipar, and the top 30cm of macadam (Banöverbyggnad or Superstructure). 3. The installation telephone and signalling infrastructure and 4. The installation of electrical infrastructure,. Indirect emissions were also calculated for the material goods being transported to the construction site during the construction period but these will not be included in the summation of the cumulative total for construction emissions.

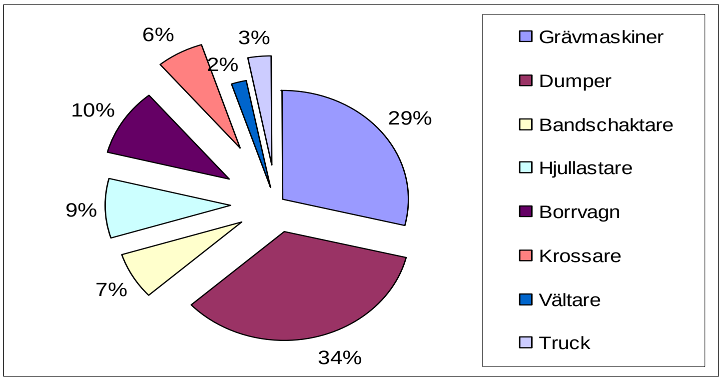
The Botniabanan is a high speed, 190km, single track railway currently under construction along the coast of the Baltic Sea in Northern Sweden. Although the general geographic context of the Botniabanan differs significantly from that of the Norrbotniabanan, certain sections have been identified as analogous. In the prognosis completed for the air pollution associated with the construction of the Botniabanan, only the direct emissions from the construction activities were estimated (Botniabanan, 2003). The estimated total operation time of machinery used for the calculation of air pollution emissions was two million operation hours with an assumed population composed of 30% excavator, 30% dump truck and 40% other contractor vehicles such as bull dozers and rolling compactors. In retrospect, the operation time included in Botniabanan's prognosis has been significantly underestimated and accordingly the emissions published in the Botniabanan prognosis are likely underestimated (Botniabanan, 2006). For this reason, a more detailed approach in estimating operation time was pursued in the completion of this analysis.

§ 2.2.1 Terracing

The construction requirements for the foundation work associated with terracing activities are highly dependant upon geographical context. Significant variability in construction activity and thus air pollution generation may be encountered on a per kilometre basis. For this reason, the completion of a relatively similar section of the Botniabanan was used as a reference for the approximate machine months needed to complete the construction of the 270km Norrbotniabanan over the predicted six year construction period.

A proportional breakdown of the machinery population was completed based on the contractor reports of four subsections of the Nordmaling administrative district of the Botniabanan. The four sections were 1.5 km, 1.8km, 5km, 11km in distance and all considered to be similar in characteristics to the projected construction of the Norrbotniabanan.

Figure 1: Prescribed Average Machinery Population for Terracing



The distance of the railway will be approximately 270km and will require approximately six years to complete construction (Norrbotniabanan, 2006). Using this information the total number of vehicles was determined by extrapolating the number of machine months required for the completion of analogous sections of the Botniabanan and extrapolating them to provide an approximate number of machines in activity over the construction period. Accordingly it will take an average of 335 machines a period of 2 975 500 machine hours or approximately six years to complete the terracing activities involved in the construction of the Norrbotniabanan.

§ 2.2.2 Tracklaying and Superstructure

The laying of the rails, ties and the upper 30cm of makadam or superstructure are completed in a single process. This process is completed with the use of a ballastplog, spårriktare, diesel locomotive and wagons and spar stabilisator (Botniabanan, 2006 and Banverket, 2006). All of the machines are rail bound. The following table is a brief description of the machinery assumed for the laying of the superstructure and track laying. The amount of time required by the laying of the track and superstructure depends highly on the number of track settings that are required to properly place the tracks. The speed of this process is approximately 600m/hr or 1.67 operation hours per km (Banverket, 2006). The amount of curves in a section does not have a significant effect on the time needed to laying tracks on a given section, only the time required for planning and preparing for such action. By these assumptions it would take 450 operation hours for the completion of work on the laying of the tracks, ties and

Table 6: Summary of Machinery for the Laying of Tracks and Superstructure

Machine Type	Motor Type	Motor Size	Typical Motor Effect
		kW	kW
Diesel Lok med Wagoner	Diesel	> 560	1200
Spårriktare	Diesel	130 - 560	440
Ballast plog	Diesel	130 - 560	500
DSS, Spårstabilisator	Diesel	130 - 560	440

§ 2.2.3 Signal and Telephone Infrastructure

For the purposes of this project, the laying of the optical fibre for telephone systems and signal systems will be considered as one action. For the signalanläggning and teleanläggning, a rail mounted excavator is used to dig a trench and lay the fibre optic cable as it advances.

The grävmaskiner is also accompanied by a small diesel locomotive carrying additional spools of fibre optic cable. Each spool holds approximately 500m of cable but depends considerably on the gage of the cable being used. The assumed speed of laying the signal and telephone lines is 2 km/hr or 0, 5 hrs/km (Banverket, 2006). The prescribed speed accounts for the time to replace the cable spool. The completion of signal and telephone lining is expected to require 135 operation hours.

Table 7: Summary of Machinery Involved in Telephone and Signal Laying

Machine	Motor Type	Motor Effect kW	Typical Motor Effect kW
Diesel Lok and Wagoner	Diesel	130 - 560	240
Rail Bound Excavator	Diesel	37 - 75	56

§ 2.2.4 Electrical Infrastructure

Complete information regarding the machinery activity associated with the electrical lining involved in the construction of a new railway had not yet been successfully collected. Accordingly, it was decided that instead of leaving the electrical installation emissions out of this analysis, an assumption that they would be four times those calculated for the signal and telephone installation was adopted. Considering the relative contribution to the total, possible error associated with this assumption is not considered to be significant. The quadrupling of activity was done by assuming that a similar machinery fleet would be used in the installation of the electrical lining but would require four times the operation time for an equivalent stretch of railway. Thus it was assumed that the installation would progress at a rate of approximately 0,5km/hr. Under these assumptions, completion of the electrical lining is expected to require 540 operation hours.

Table 8: Summary of Assumed Machinery Involved in Electrical Installation

Machinery Assumed fleet to complete 1km of Electrical Lining	Motor Type	Motor Effect kW	Typical Motor Effect kW
The same as Signal and Telephone	Diesel	130 - 560	240
The same as Signal and Telephone	Diesel	37 - 75	56

The following table is a brief summary of the emissions factors for the construction of one kilometre of railway based on machinery activity, excluding the foundation work. The emission rates presented below correspond to the fuel combustion related emissions associated with the heavy machinery operation involved in the completion of each phase of railway construction with the exception of terracing which at this time has not been approached on a per kilometre basis due to complications associated with the availability of information.

Table 9: Emissions per Kilometre of Railway

Construction Phase	CO	NMVOC	NOx	Partiklar	N2O	CH4	NH3	CO2	SO2
	tonnes/km								
Superstructure and Track Laying	0,004	0,002	0,016	0,001	0,000	0,000	0,000	0,177	0,000
Signal and Telephone Lining	0,000	0,000	0,001	0,000	0,000	0,000	0,000	0,013	0,000
Electical Lining	0,001	0,000	0,002	0,000	0,000	0,000	0,000	0,050	0,000
Total	**0,005**	**0,002**	**0,019**	**0,001**	**0,001**	**0,000**	**0,000**	**0,239**	**0,000**

§ 2.3 Calculation of Recovery Time

The operation of the Norrbotniabanan once construction is finished will result in significant reductions in the emissions of air pollutants due to transportation in Norrland each year. It is expected that the operation of the Norrbotniabanan will result in significant changes to the transportation system in Norrland: 20 833 333 vehicle kilometres by truck and trailer units, 23 130 680 vehicle kilometres by personal automobiles and 125 000 000m net ton kilometres will be transferred to electric train and will accordingly result in significant reduction of the annual air pollution from transportation in northern Sweden (Banverket, 2003).

Table 10: Air Pollution Reductions from Goods Traffic

Species	Reductions from Goods Traffic (tonnes/year)		
	Truck with Trailer	Sea Freight	Flight
NO_x	193,05	40,00	-
VOC	23,26	1,25	-
SO2	1,28	5,00	-
Partiklar	1,16	1,75	-
CO2	18 216,67	2 062,50	-

Table 11: Air Pollution Reductions from Person Traffic

Species	Reductions from Person Traffic (tonnes/year)		
	Personal Car	Bus	Flight
NO_x	4,53	0,00	0
VOC	4,43	0,00	0
SO2	0,02	0,00	0
Partiklar	0,00	0,00	0
CO2	3 310,00	0,00	0

Table 12: Combined Air Pollution Reductions

Species	Reductions (tonnes/year)
NOX	237,58
VOC	28,94
SO2	6,30
Partiklar	2,91
CO2	23 589,17

The following table presents calculations for the approximate annual emissions associated with the annual operation of the Norrbotniabanan. The emissions were calculated accounting for the quantities of fossil fuel consumed by maintenance vehicles in the operation and maintenance of each kilometre (IVL, 2003). An updated prognosis of the reductions from the operation of the Norrbotniabanan is currently underway and BAS 2020 will be used to make new calculations of CO2 etc. (Banverket, 2006). The calculations made in this report should be revised when this information becomes available.

Table 13: Emissions from Operation and Maintenance (IVL, 2003)

Species	Emissions (tonnes/year)
NO_x	2,54
HC	0,15
SO2	0,02
CO2, fossilt	549,83

The operation and maintenance emissions were subtracted from the combined annual air pollution reductions from the emissions related to the operation and maintenance of the Norrbotniabanan to generate a value for the emissions balance annually after the completion of the construction period. The net annual emissions reductions or annual emission currently projected to be realized annually throughout the 60 year lifespan of the Norrbotniabanan.

Table 14: Net Emissions Annual Emissions Reductions (Banverket, 2003)

Species	Net Reductions (tonnes/year)
NOX	235,04
VOC	28,79
SO2	6,28
Partiklar	2,91
CO_2	23 039,34

§ 2.4 Peak Emissions and MKN's

The machinery population data that formed the foundation for the projected number of machines and accordingly the quantity of NO_x, PM10, HC, CO and emissions distributed throughout the time series for each urban construction event along the Norrbotniabanan was gathered from monthly contractor reports outlining the number and type of machines that were used in the terracing of a five kilometre section of the Botniabanan in the Nordmaling region. This section is considered to be a reasonable analogy to the predicted Norrbotniabanan including topographic context (Botniabanan, 2006 and Norrbotniabanan, 2006). On site emissions are expected to be highest during the terracing phase of construction. As such, the effect on the environmental quality norms will be highest at this time.

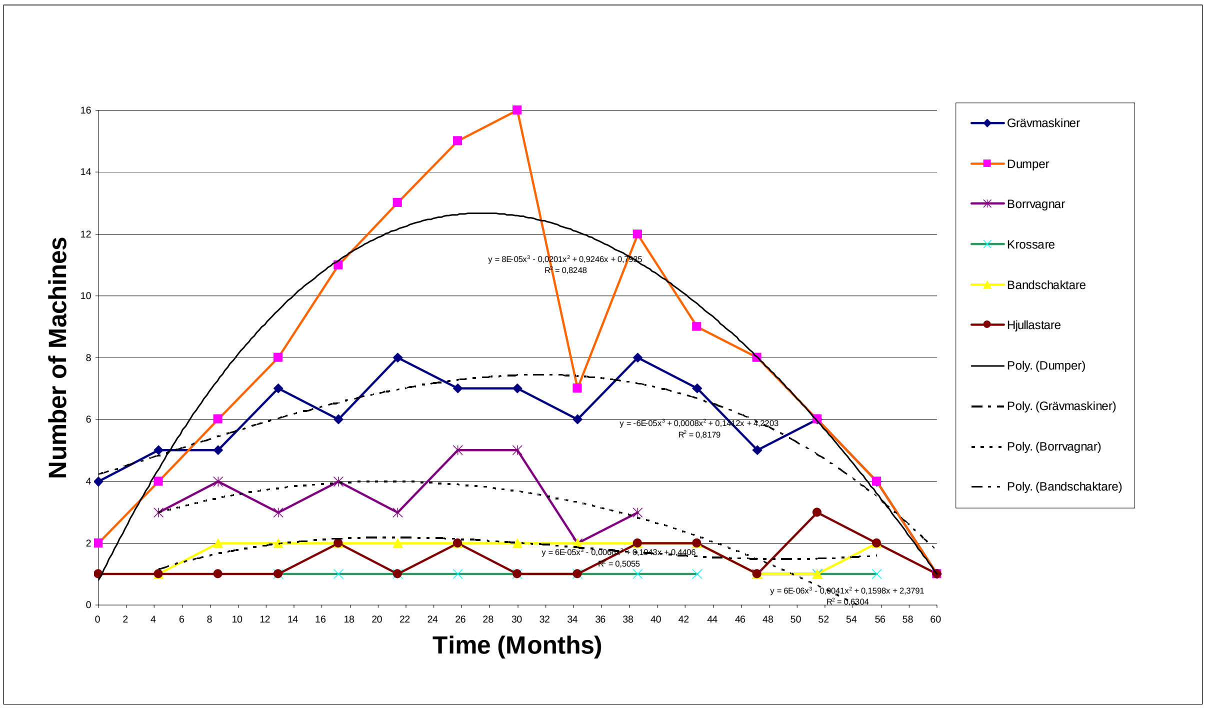
The methods used for predicting the machinery activity over time do not cover all possible variations in the construction. It is possible that the construction activities will be conducted at higher intensity over a shorter construction period to reduce the inconvenience due to machinery operating within urban areas. Accordingly, the peak number of vehicles and machinery may be higher than that presented but likely over a shorter period of time. In the event of a section with highly varied topography, a section including bridges, tunnels etc. the emissions may be higher than those projected here.

The number of the machines was extrapolated from the five kilometre section to a twenty kilometre section by assuming the same number of machines over a construction period four times that of the five kilometre section. At the time of the analysis, a reliable way to correlate number of machines to distance according to distance terraced had not been developed. Accordingly, the assumption of equivalent machinery over an extended time period was considered the most reliable projection at present. The data for the time series of 60 months was developed by simply changing the time series intervals from one month to 4, 28 months (adjusted from four to be able to have a zero month).

The detailed analysis of the Nordmaling section was done in part to enable the isolation of a peak emissions point or period in order to be able to accurately depict the maximum effect of the construction activities on the environmental quality norms (MKN). The peaks were found for each of the modelled pollutants by solving the derivatives for second order polynomial trendlines used to describe the machinery population. The peak year, was found by taking the six months on either side of the peak.

The initial machine population data was used to generate trend lines in order to approximate the distribution of the machinery throughout the construction period. The use of assumed trends in the machinery populations was pursued in order to facilitate ease of handling further information by being able to employ mathematical operations to ease the population descriptions. In short, the trends were developed to ease the use of the data in further stages of the analysis. The following figure also serves as a summary of the assumed trends in the modelling of the machinery activity data and corresponding air pollution emissions.

Figure 2: Terracing Machinery (Botniabanan, 2006)



The following will be an explanation for each of the assumed trends on an individual basis and a presentation of the reasoning for each of the machinery types. It is possible to increase the ability of trend to describe the data by increasing the order of the polynomial but this also increases the difficulty and time associated with using the trends. For this reason, improved precision in predicting the population was sacrificed in favour of time. Once each of the trends were accepted, they were used to calculate the monthly machine hours according to the assumed activity per month per machine to generate a value of machine operation hours per month for each type of machinery.

Figure 3: Modelled Peak Machine Activity During Terracing

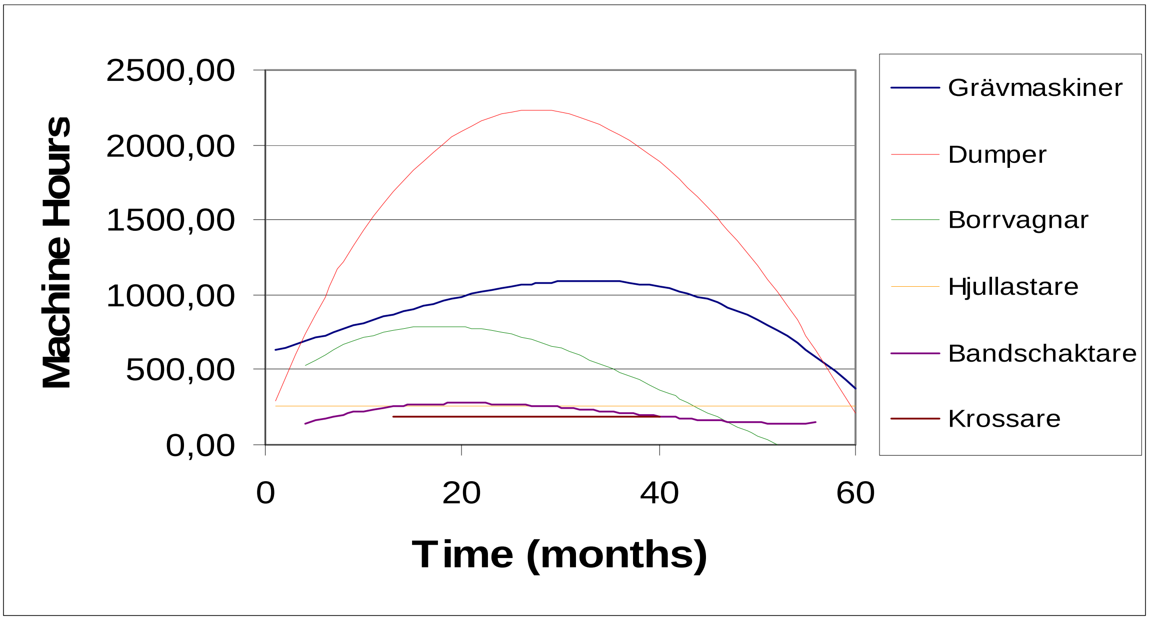
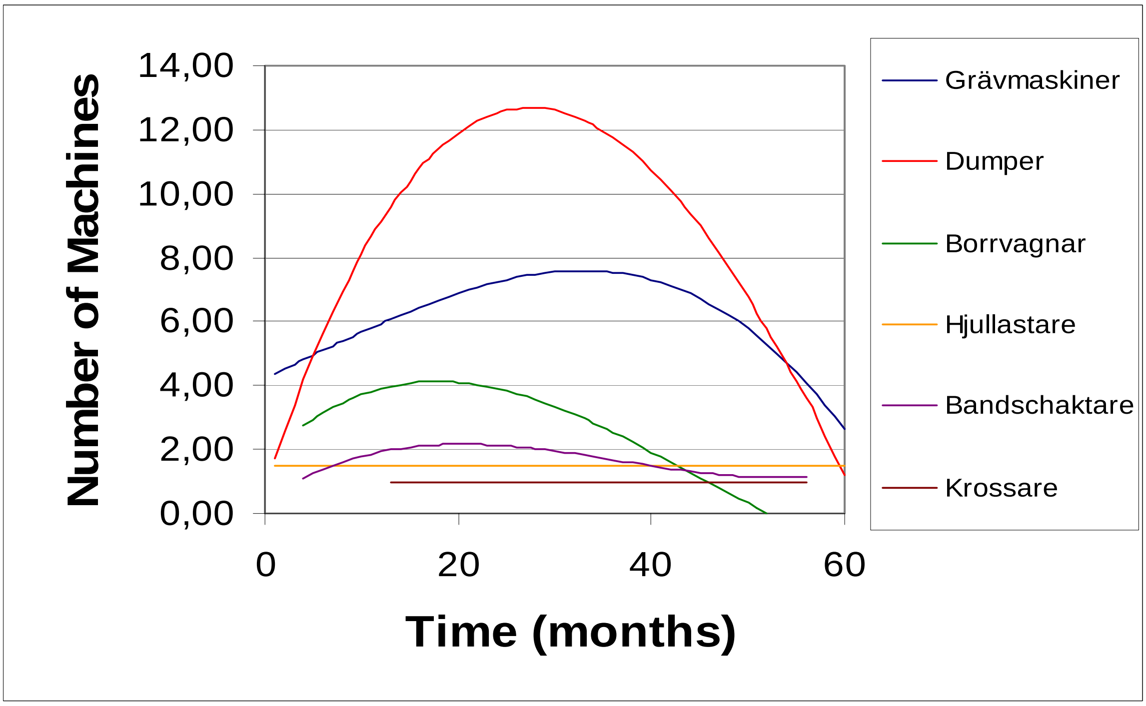


Figure 4: Modelled Machine Hours for Peak Terracing Activities



The following figure illustrates the trends in operation hours per month by machinery type. The population activity was converted from number of machines to operation hours based on an assumption of a maximum of 12 hours per work day, four work days per week and four weeks per month (Botniabanan, 2006). Each of the machinery type also had a activity weighting incorporated to describe what proportion of the maximum operation of activity based on the relative annual activity proposed in previous emissions inventories for heavy machinery. (IVL, 2003)

Figure 5: Peak Modelled NOx Emissions Rate

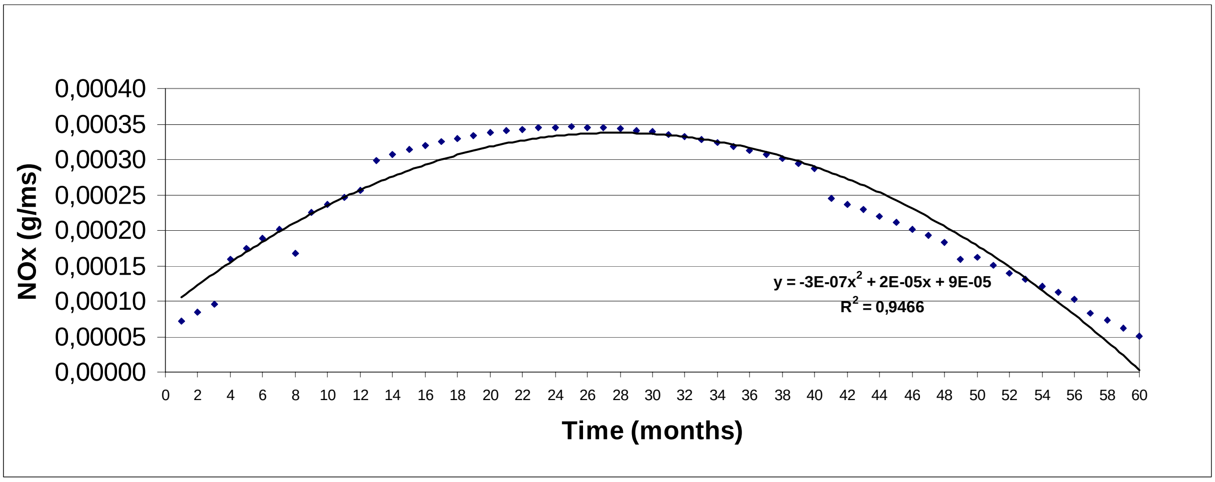


Figure 6: Peak Modelled PM10 Emissions Rate

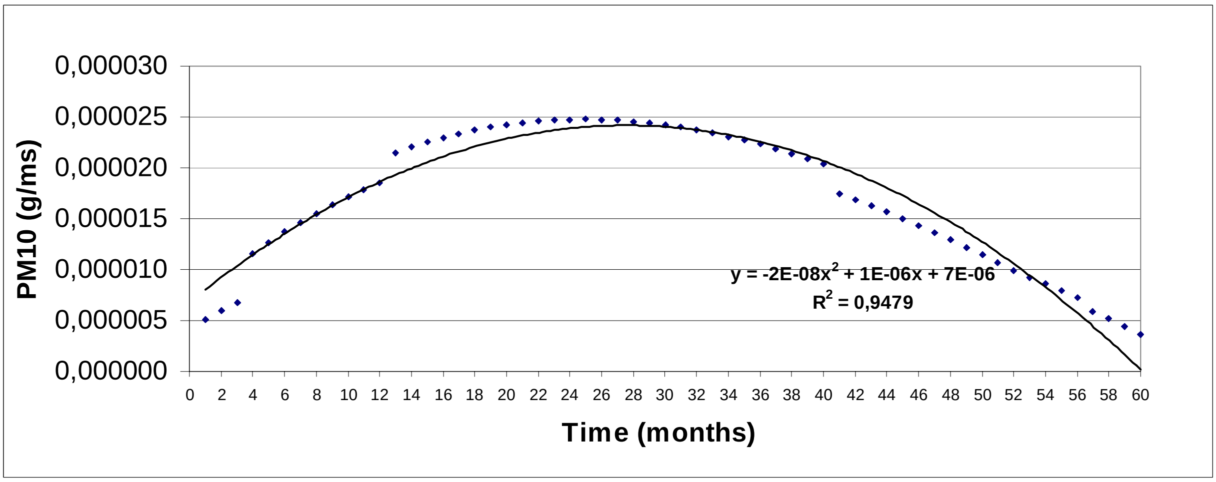


Figure 7: Peak Modelled CO Emissions Rate

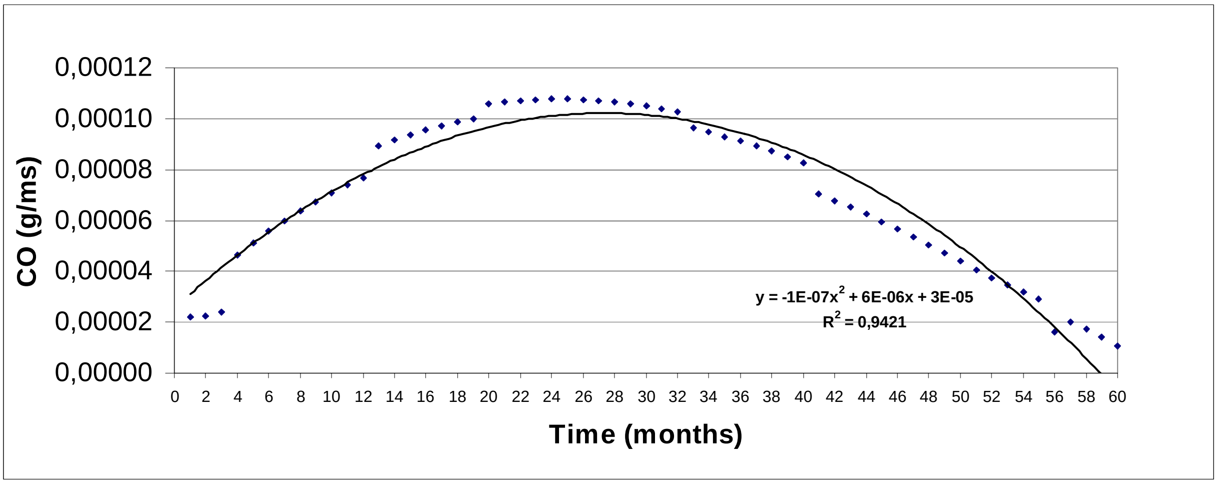
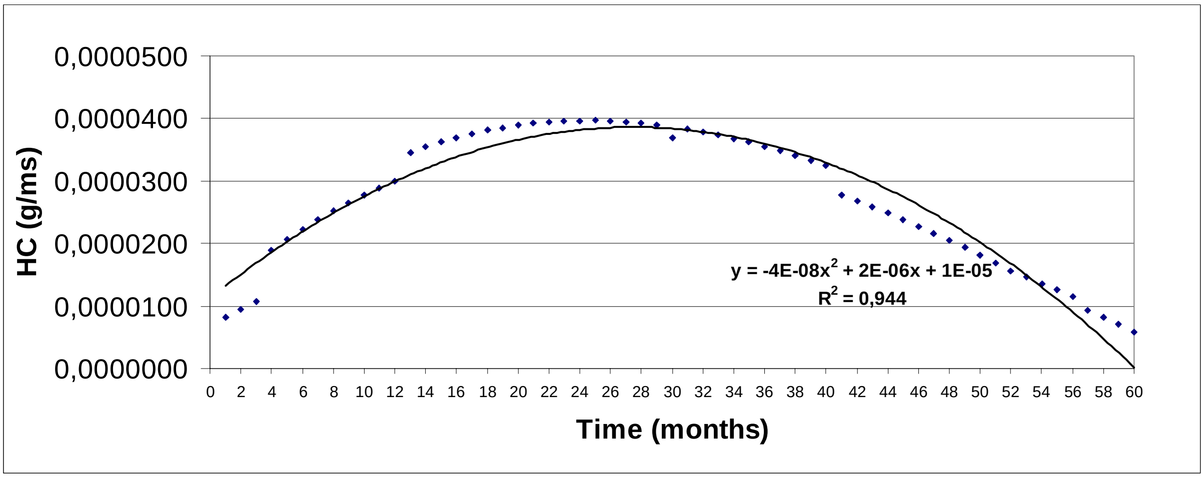


Figure 8: Peak Modelled HC Emissions Rate



§ 2.5 Modelling Activities

Modelling was done using the facilities provided by Miljökontoret Luleå Kommun. The model that has been used to complete the disperion modelling requirements of this project was the Svenska Meteorologiska och Hydroliska Institutet's (SMHI) "SMHI Dispersion 2.1."

The assumed operation time is four weeks per month, four days per week, and an average of 10.5 operation hours per day resulting in 604, 800 operation seconds per month. The collective emissions rate was averaged over the 20 km stretch to be input as emissions in g/ms. It was not possible to capture the peak emissions themselves due to the necessity of inputting one singular rate of emissions into the modelling software. It was supposed that the input of the average over the whole 60 months would not provide adequate account of the peak and that accepting the maximum value would grossly over exaggerate the emissions from the construction. Therefore the compromise that was arrived at was to take the average of the six months before and after the peak event (in total 12 months). It is believed that this provides an adequate representation of the higher end emissions rates while minimizing the over exaggeration of the emissions. The hours of 06:00 until 17:00 on Monday, Tuesday, Wednesday and Thursday were assigned a loading factor of one while all others were assigned a loading factor of zero. A loading factor of one implies that emissions occur during that hour and a loading factor of zero implies that emissions do not occur during that hour. The emissions height was assumed to be 2m to account for the raised exhaust pipes employed in most heavy machinery. Modelling activities were completed for HC, CO, NOx and PM10. There was occasion to model emissions of SO2 but the emissions rate calculated did not the input requirement of exceeding 0,000001 g/ms.

Table 15: Emissions Rates Input into the Dispersion Model

Pollutant	Emissions Rate (g/ms)
NO_x	0,000342
PM10	0,000024
SO_2	0
HC	0,000039
CO	0,000107

§ 2.6 Relationship between NOx and NO2

Although all of the calculations, modelling and general mathematic description of airborne compounds containing Nitrogen and Oxygen are done using NO_x, the regulations and standards controlling nitrogen are directed at the control of NO_2, which is exceptionally pertinent to human health. The various reactions that convert primary NO to NO_2 are listed below. This is not considered to be an exhaustive list but is a proper representation of the variety of circumstances influencing the generation of NO_2 following the primary emission of NO (Brimblecombe, 1986).

Formula 6: Oxidation of Nitric Acid by Oxygen

$$2NO + O_2 \rightarrow NO_2 + O_2$$

Formula 7: Atmospheric Reaction of Ozone with Nitric Acid

$$NO + O_3 \rightarrow NO_2 + O_2$$

Formula 8: Reaction of Nitric Acid with Oxygen Radical

$$NO + O^{\cdot} \rightarrow NO_2$$

Formula 9: The Reaction of Nitric Acid with the Methyl Peroxy Radical

$$CH_3O_2 + NO \rightarrow CH_3 + NO_2$$

The very complex reaction involving C_yH_x components to produce O_3 from remote urban areas is transported by wind from the south and varies considerably throughout the year. The photochemical dissociation ultraviolet light levels (Brimblecombe, 1986).

To calculate and present the NO_2 as a component of calculated NO_x concentrations, Luleå Kommun has recommended the relationship between NO_x and NO_2 in central Luleå to be as follows (Luleå Kommun, 2006):

Formula 10 $$[NO_2] = 0,\ 4043\ [NO_x] - 11,\ 4$$

In order to provide an approximate description of the NO_2 content of the modelled NOx values the relationship recommended by Luleå Kommun has been adopted. However, the relationship is victim to the uncertainty associated with NO_2 content especially at lower concentrations of NO_2. In average annual measurements published by the Luleå Kommun Miljökontoret, the proportion of NO_x constituted by NO_2 varies between 27% and 42% with an average of 31% for the six sites with NOx concentrations above 38µg/m^3 (Luleå Kommun, 2003). For this reason, the comparisons that follow will be completed with the recommended relationship but will be followed by a value which will correspond to 31% of the NO_x concentration. The proportion of NO_2 included in the NO_x designation increases significantly as the total NO_x concentration decreases (Luleå Kommun, 2003) and thus for values below 38 µg/m^3 is not considered valid at this time. It should be noted that the highest average value reported in the 2001/2002 investigation was 76µg/m^3 NO_x corresponding to a concentration of 23, 6 µg/m^3 NO_2 (Luleå Kommun, 2003).

§ 2.7 Indirect Emissions Related to Material Transportation

Although the emissions that will be concentrated in both intensity and proximity as an area source at the construction site are most pertinent to the prediction of adverse effects from the construction activities there will also be air pollution loadings as line sources on rail systems and motor ways as materials necessary for the construction activities are transported to the construction site.

In the estimations for emissions due to material transportation, the sum amount of materials necessary for the assembly of the railway as a whole was dissected into rails, slipars, and macadam as well as an additional category for "other" materials. The distance and mode by which each of these materials is transported varies considerably. The rails are imported approximately 2500km from Austria and transported by electric train (Banverket, 2006). The slipers (ties) come from northern Sweden, approximate distance of. 400km and are transported by electrical train. The macadam is expected to come from a local source less than 100km in distance from the construction site. Fuel as well as materials other than slipars, macadam and rails were included in the "Other" category and assumed to come from a central distribution depot in southern Sweden (Banverket, 2006). For the transportation of the macadam, 80% of the tonne kilometres are expected to be shouldered by electric train with the remainder being transported by regional traffic transport truck (Lastbil med slap) (Banverket, 2006).

Table 16: Material Inputs for Railway Construction (IVL, 2003)

Materials	Mass (tonnes per kilometer)
Rail	144,00
Slipar	321,60
Makadam	4 887,17
Other	1 540,45
Total	6 893,22

Table 17: Material Transport per km Railway

Material	Makadam	Slipar	Other	Rail	Total
Estimated Haul Length (km)	100	400	1000	2500	-
Lastbil Euro2, Medeltung, regional trafik (NTM)	20%	0%	0%	0%	-
Dieseltåg, gods, NTM	0%	0%	0%	0%	-
Transportarbete goods	80%	100%	100%	100%	-
Transported Goods (tonnes/ km railway)	4 887,17	321,60	1 540,45	144,00	-
Transported Goods (tonne km)	488 716,80	128 640,00	1 540 453,43	360 000,00	-
Lastbil Euro2, Medeltung, regional trafik (NTM) (tonne km)	97 743,36	-	-	-	97 743,36
Dieseltåg, gods, NTM (tonne km)	-	-	-	-	-
Electric Train goods (tonne km)	390 973,44	128 640,00	1 540 453,43	360 000,00	2 420 066,9

Table 18: Rate of Emissions Associated with Transportation of Materials (IVL, 2003)

Pollutant	Emissions (tonnes/km railway)	Emissions (kg/km railway)
CO (luft)	0,01	14,03
CO2 , biogent (luft)	1,06	1 063,62
CO2 , fossilt (luft)	15,40	15 402,43
HC (luft)	0,01	13,03
N2O (luft)	0,00	0,05
NOx (luft)	0,12	120,82
Partiklar (luft)	0,00	2,62
SO2 (luft)	0,01	5,24
Cd (aq)	0,00	0,00

§ 3 Results

The air emissions resulting from the construction activities associated with the Norrbotniabanan are presented in tabular form as well as being modelled in order to interpret their influence on human health and environmental impact.

§ 3.1 Direct Construction Emissions

The phase of construction that is responsible for the majority of machinery activity and accordingly the majority of combustion related air pollution emissions is the foundation work and laying of the under ballast, referred to collectively as terracing. The terracing of the 270km of the Norrbotniabanan was predicted to take an average of 335 machines six years to complete under the assumption that the topography throughout the course of the Norrbotniabanan is approximately similar to the Nordmaling section of the Botniabanan.

The following table is a breakdown by machine type of the air pollutant emission that has been calculated for the terracing.

Table 19: Air Pollution Emissions from Terracing

Machine Type	CO	NMVOC	NO_x	Partiklar	NH_3	SO_2
	tonnes					
Bandschaktare	39,93	13,70	118,33	8,01	0,02	0,02
Dumper, ramstydra	270,76	101,32	933,65	65,18	0,16	0,17
Grävmaskiner, band	157,46	58,92	542,96	37,90	0,09	0,11
Hjullastare	66,98	24,02	177,01	13,90	0,03	0,05
Vältar	6,55	2,85	16,42	1,60	0,00	0,00
Truck	8,86	3,18	23,41	1,84	0,00	0,00
Borragr. Entr.	132,85	47,63	351,10	27,58	0,06	0,00
Stenkrossare	130,31	48,76	449,35	31,37	0,08	0,00
Total	**813,71**	**300,38**	**2 612,22**	**187,38**	**0,44**	**0,35**

Table 20: Greenhouse Gas Emissions from Terracing

Machine Type	N_2O	CH_4	Ultimate CO_2	End of Pipe CO_2	Total CO_2e
	tonnes				
Bandschaktare	3,69	0,53	7 323,28	7 320,16	8 474,34
Dumper, ramstyrda	27,28	3,90	54 343,37	54 320,68	62 859,05
Grävmaskiner, band	15,86	2,27	34 131,71	34 118,51	39 038,51
Hjullastare	5,52	0,79	14 385,01	14 379,67	16 091,73
Vältar	0,45	0,06	464,97	464,39	606,45
Truck	0,73	0,10	2 397,50	2 396,80	2 625,09
Borragr. Entr.	10,94	1,56	17 436,38	17 425,78	20 850,27
Stenkrossare	13,13	1,88	23 539,11	23 528,19	27 637,56
Total	77,60	11,09	154 021,32	153 954,18	178 183,00
GHG's i CO2e	**24 055,96**	**232,80**	**-**	**153 954,18**	**178 242,94**

The following table presents the air pollution emissions calculated for Norrbotniabanan assuming that the air pollution resulting from the electrical lining is approximately four times the signal and telephone installation.

Table 21: Air Pollution Emissions from Superstructure and Tracklaying

Construction Phase	CO	NMVOC	NOx	Partiklar	N2O	CH4	NH3	CO2	SO2
	tonnes								
Superstructure and Tracklaying	1,133	0,453	4,354	0,310	0,122	0,017	0,001	47,678	0,000
Signal and Telephone Lining	0,043	0,016	0,152	0,012	0,004	0,000	0,000	3,389	0,000
Electrical Lining	0,170	0,065	0,610	0,047	0,017	0,002	0,000	13,554	0,000
Total	**1,346**	**0,535**	**5,116**	**0,369**	**0,143**	**0,020**	**0,001**	**64,621**	**0,000**

The following table summarizes the breakdown of the total emissions associated with construction of the 270km course of the Norrbotniabanan.

Table 22: Summary of Construction Related Emissions

Species	Terracing	Signal & Telephone Lining	Tracklaying & Superstructure	Electrical Lining	Total Construction Emissions
	tonnes				
CO	813,71	0,04	1,13	0,17	815,05
NMVOC	300,38	0,02	0,45	0,07	300,92
NO_x	2 612,22	0,15	4,35	0,61	2 617,34
Partiklar	187,38	0,01	0,31	0,05	187,75
NH_3	0,44	0,00	0,00	0,00	0,44
SO_2	0,35	0,00	0,00	0,00	0,35
N_2O	77,60	0,00	0,12	0,02	77,74
CH_4	11,09	0,00	0,02	0,00	11,11
CO_2	153 954,18	3,39	47,68	13,55	154 018,80
Total CO_2e	178 242,94	4,69	85,83	18,81	178 352,27

Figure 9: Breakdown of Total Air Pollutants

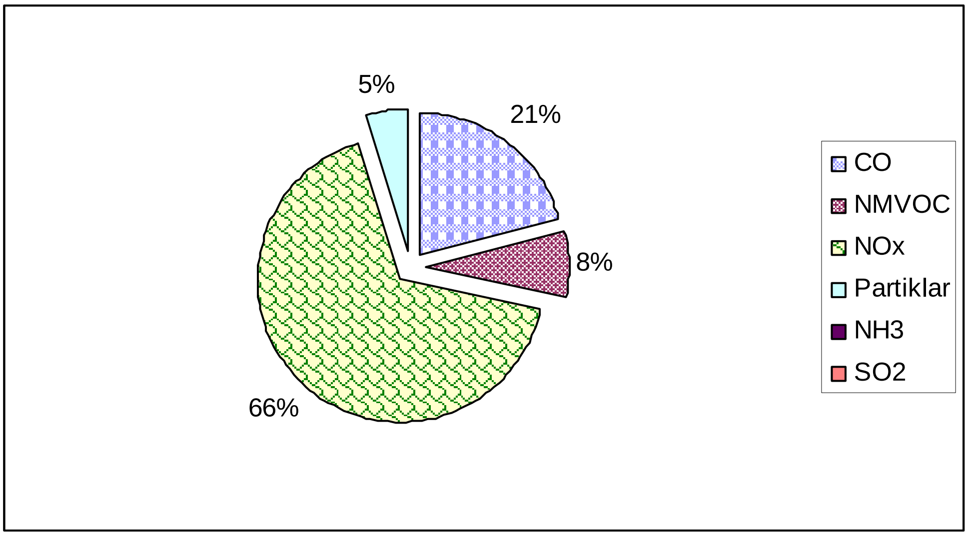
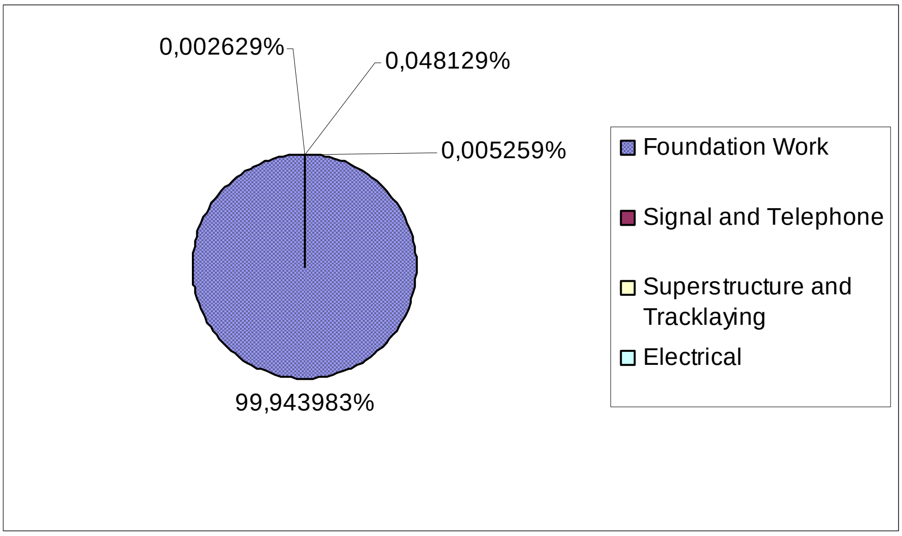


Figure 10: Breakdown of CO2 by Construction Phase



It may help to rationalize the air pollution emissions by providing a comparison in terms of everyday objects: The construction emissions are roughly equal to the operation of 10 260 average Swedish cars' CO2 emissions and the NO_x emissions of 46 530 average Swedish cars during the same time period, under the assumption that an average Swedish personal automobile emits 2.5 tons CO2 / year (Konsumentverket, 2006) and 9,375 kilograms NO_x / year (Vägverket, 2001). Under the same assumption, the net reductions in CO2 over the lifespan of the Norrbotniabanan is equivalent to the emission generated by approximately 8,500 average Swedish cars over a period of 60 years and the net reductions in NO_x are comparable to the emissions generated by approximately 20 425 Swedish personal automobiles over a period of 60 years.

§ 3.2 Modelling & Effect of Emissions on Local Air Quality

In order to properly account for the true impact of air pollution generated during the projected construction activities, the dispersion of the NOx, PM10, HC and CO generated during the peak year of construction activity are modelled. Also included in each of the modelled sections is a brief description of the human health effects of each of the modelled air pollutants. The modelling attempts to depict the influence the peak activity of construction would have on air quality. The peak construction activity is expected to occur during the terracing or foundation work phase of construction. The terracing modelled implies a section of low topography and relatively low work demands for completion. A tunnel section or section with significant variation in topography may influence machinery activity to result in a greater rate of emissions, longer duration of emissions period or both. As established in the Direct Construction Emissions section, the emissions associated with the later phases of railway construction are not of the same magnitude as those generated by the terracing.

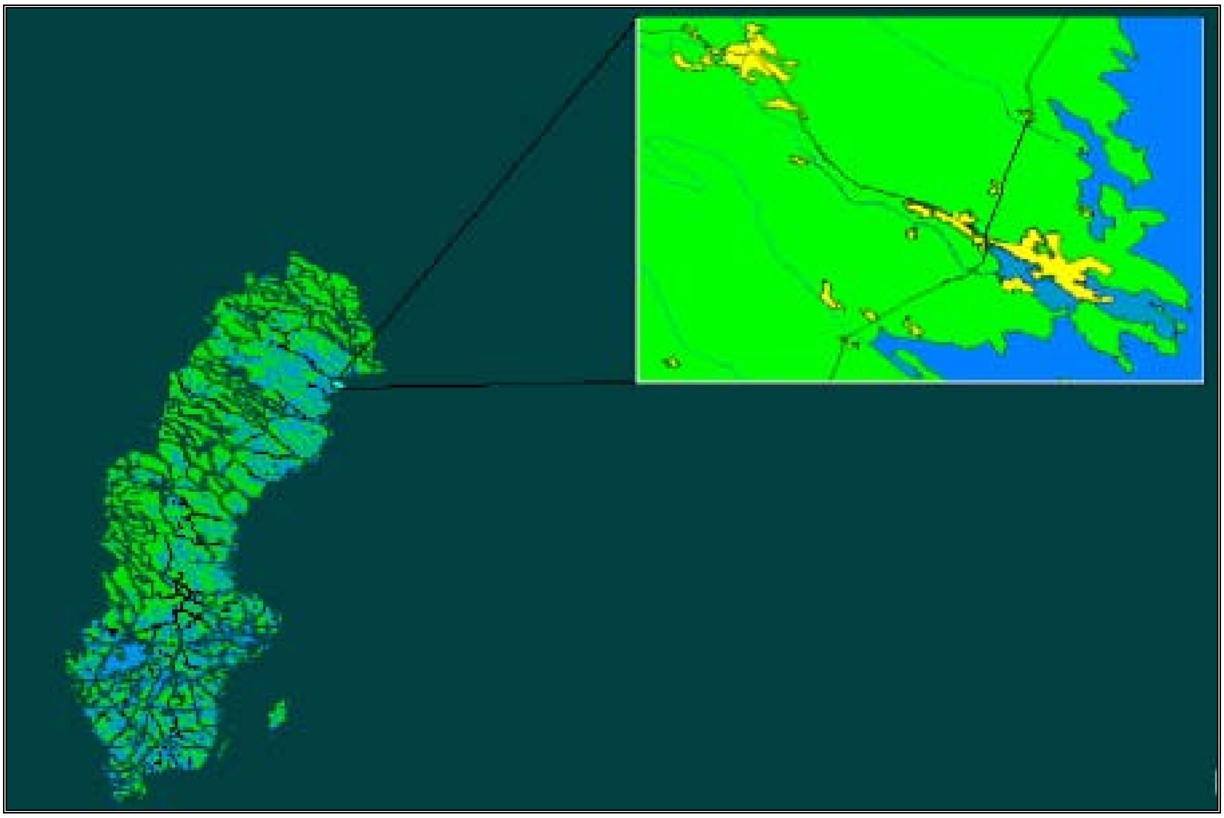
Dispersion modelling has only been completed for Luleå. This is considered to serve as a valid approximation as to what will occur in Skellefteå and Piteå. The background concentrations are expected to be less than or equal to those experienced in Luleå. The change in isolines above the background concentration represents the likely events in both of the other cities. In order to properly describe the potential emissions situations in all communities through the extrapolation of modelling done for Luleå, exceptional effort was devoted to ensuring that the possible air pollution situations in Luleå were explored in detail.

The air pollution dispersion modelling has been completed for three years assuming an emissions rate calculated from the average emission rate for the twelve months surrounding the modelled peak machine activity. Accordingly, the value of the emission rate should represent the highest emissions over one year. From the three years modelled using the highest annual average for the emission rate, the highest year has been accepted and is presented below. It is expected that changes in meteorological conditions are responsible for the variation between years, especially the influence of inversion conditions during the winter months. Initially, SO_2 had also been a candidate for modelling but the calculated emission rate peak was less than 0.000001 g/ms, the lowest acceptable input value for the modelling software.

The modelling has been completed for two different stretches dissecting different pieces of Luleå but only the “High Alternative” is included in this report. The final course of the Norrbotniabanan is not yet determined during the completion of through Luleå, Piteå and Skellefteå. For this investigation, reason and for the applicability of the Luleå modelling to the other communities in this study, the higher of the two potential alternatives has been presented. The modelled emissions that are presented best in order to better illustrate the influence of air emissions generated by the construction activities regardless of community or ultimate railway course.

The “High Alternative” line presents the alternative, in which the line source will begin at the northeast corner of the built up area of Luleå, passes through Luleå Centrum and extend to the steel plant located at the southeast corner of the city. This line source will represent the higher end of the range of impact on the air quality in Luleå. The high alternative option for the modelling of the dispersion from the terracing activities completed during the year with the highest peak emissions rate and carried out in the highest air emissions corridor in Luleå. The high alternative has been modelled using a zero background concentration to accentuate the contribution of construction activities and using an assumed background concentration of 70μg /m^3 a typical concentration for Luleå Centrum (Luleå Kommun, 2003) to outline the potential influence on the air quality as it relates to human health. The PM10 modelling high alternative was completed using a background concentration of 0μg /m^3 to exhibit the contribution of the construction activities and using a background concentration of 18.7μg /m^3 (Luleå Kommun, 2003) to show the resultant levels of PM10 and their proximity to existing standards.

Figure 11: Subject Area of Modelling Activities

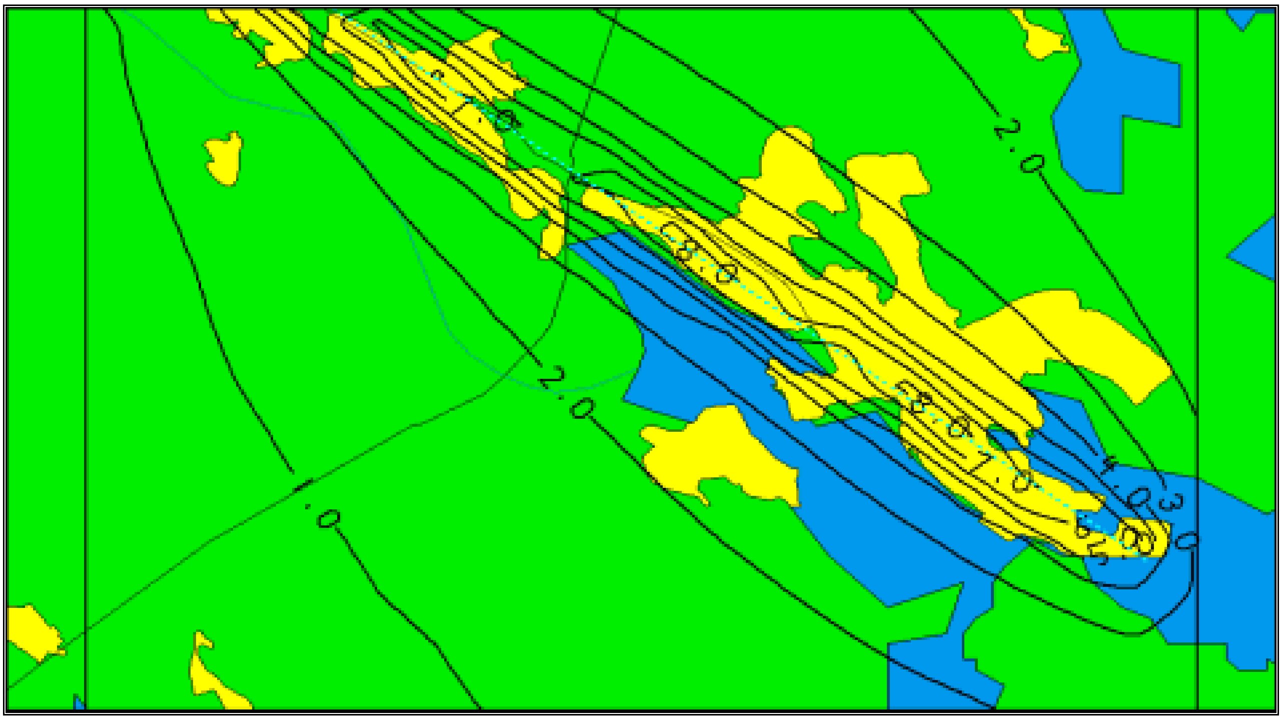


§ 3.2.1.1 NOx

The grouping of oxides of nitrogen or NO_x represents a number of highly reactive gases containing nitrogen and oxygen which are primarily formed during the combustion of fuels at high temperatures. Emissions of NO_x are directly tied to the combustion of fossil fuels and more specifically the oxidization of carbon in the presence of the nitrogen component of air (approximately 70%) (USEPA, 2006). Oxides of nitrogen may have detrimental impacts on the environment both as primary and secondary pollutants. NO_x may react with volatile organic compounds to form tropospheric ozone, a principal component of ground level photochemical smog, whose proliferation may result in the damage of lung tissue and reduction of lung function in high risk groups such as seniors, children, asthmatics and those who exercise outside (Environment Canada, 2006). NO_x may react with other substances in the atmosphere to create acids which may be deposited in terrestrial and aquatic ecosystems through the action of acid precipitation and particulate acid fallout (USEPA, 2006). Acid deposition may lead to the acidification of water bodies, corrosion of infrastructure and damage of buildings and historical monuments. Nitrogen deposition in water bodies may also contribute to nutrient loading of water bodies and result in the eutrophication of the aquatic ecosystem. NO_x may also react with other chemical constituents in the air column to form particulate matter and a variety of toxic pollutants. Nitrogen based particulate matter such as nitric acid may cause damage to lung tissue and exacerbate existing pulmonary disease (USEPA, 2006). Toxic chemicals originating from NO_x such as the nitrate radical, nitrosamines and nitroarenes can be toxic to humans and some may even cause biological mutations (USEPA, 2006). Emissions of NO_2 and nitrogen based particulate matter may also be associated with the impairment of visibility in urban areas.

The following figure illustrates the modelled contribution of construction activities to the annual average of NO_x considering a background concentration of 0µg /m^3 over the high alternative course of the construction. The distance between each isoline indicates a change in NO_x concentration of 1,0µg /m^3.

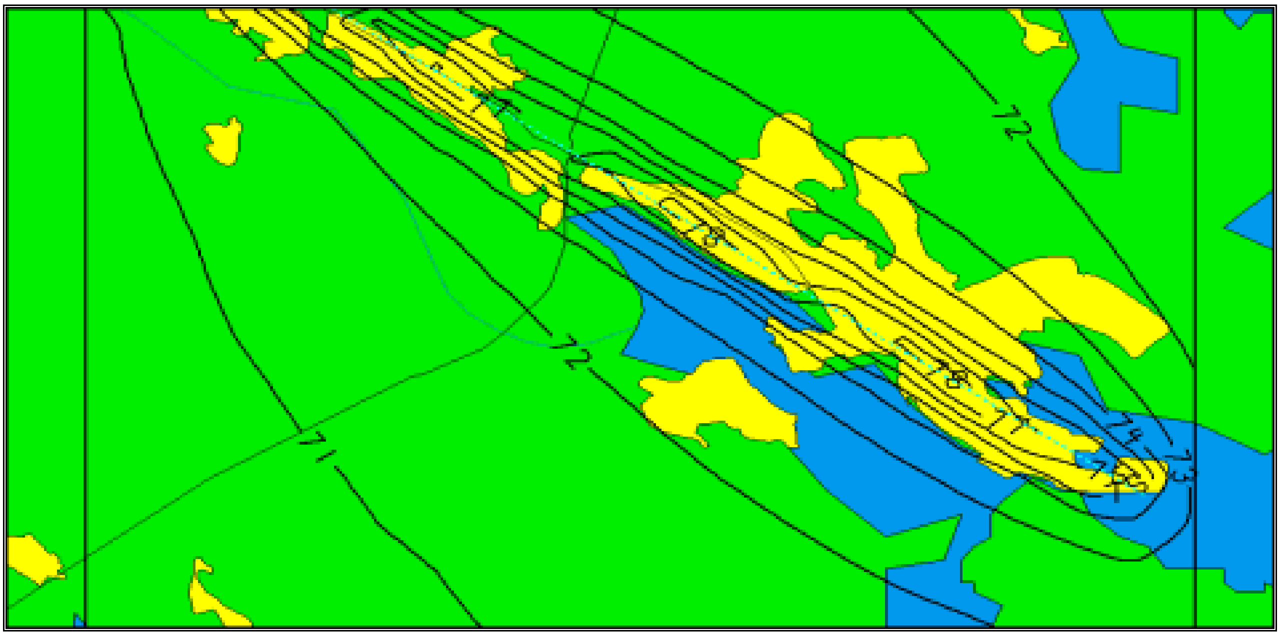
Figure 12: NOx Annual Average (µg /m^3) Assuming Background of 0 µg /m^3



4 cm =5km

The following figure illustrates the influence that the modelled emissions have on an assumed annual average background concentration of 70µg /m^3. Each isoline indicates a change of 1µg /m^3.

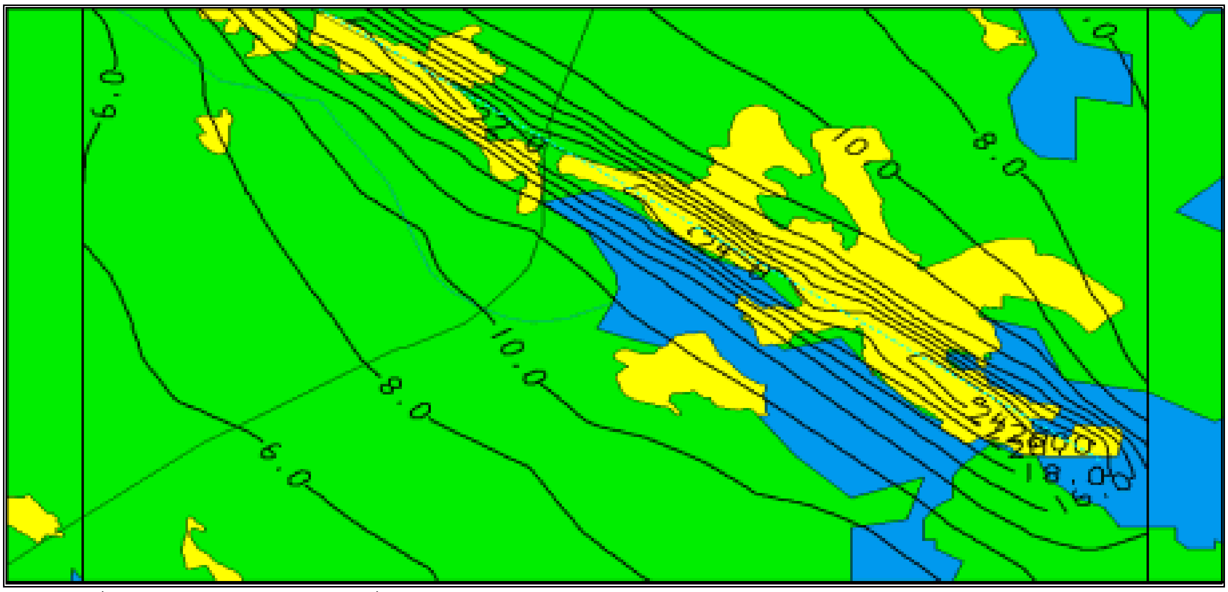
Figure 13: NOx Annual Average (µg/m^3) Assuming Background of 70µg /m^3



4 cm =5km

The following figure illustrates the contribution of the construction emissions in terms of the ninety eighth percentile value for one year's daily average concentrations of NO_x assuming a background concentration of 0µg /m^3.   Each isoline indicates a change of 2µg/m^3 of NO_x.

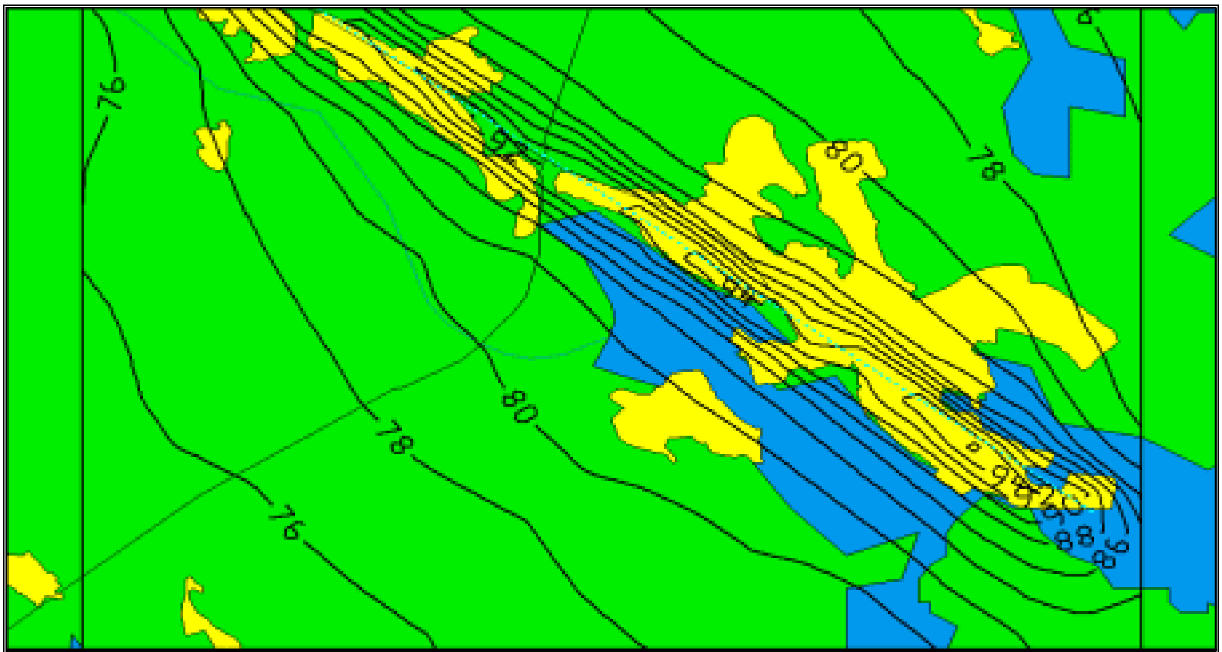
Figure 14: NO_x 98 % Percentile Value (µg/m^3) Assuming Background of 0µg/m^3



4 cm =5km

The following figure provides an illustration of the influence of the construction activities on the ninety eighth percentile value for NO_x assuming an average background concentration of 70µg /m^3. Each isoline indicates a change of 2µg /m^3 of NO_x.

Figure 15: NO_x 98% Percentile Value (µg/m^3) Assuming Background of 70µg /m^3



4 cm = 5km

According to Formula 5, the NO_2 proportion of the total concentration of NO_x increases as the total concentration of NO_x increases. Using formula 5, one may conclude that the annual average NO_x concentration of 70-78 $\mu g/m^3$ in the vicinity of the line source corresponds to a range of 16,90 – 20,14 $\mu g/m^3$ of $NO_{2,}$. One may alternately gather from the approximation that "31% of the NO_x is NO_2," that the range of NO_2 modelled above is 21, 70 – 24, 18 $\mu g/m^3$. As the MKN for NO_2 is 40$\mu g/m^3$, the modelled influence of the construction emissions does not cause the NO_2 concentrations to approach the MKN for annual average concentrations of NO_2. However, the environmental objective that has been outlined for 2010, an annual average of 20$\mu g/m^3$ NO_2, is approached and exceeded using both NO_2 calculation methods.

Using Formula 5, the range of 98th percentile value for daily average NO_x values of 76 – 94$\mu g/m^3$ may be equated to a range of NO_2 concentrations of 19, 33 - 26, 60$\mu g/m^3$. Using the approximation that 31% of NO_x is NO_2, the range of modelled 98th percentile values is 23, 56 – 29, 14$\mu g/m^3$. Neither of which approaches nor exceeds the MKN for the 98th percentile value for the average of daily NO_x, 60$\mu g/m^3$.

The environmental quality norm for NO_x in ecosystems is 30$\mu g/ m^3$ as a yearly average. It is not believed that this will be approached or exceeded during construction activities due to the low levels experienced in rural Sweden, the relatively low topography of the projected construction course and inferences from the modelling completed for the urban settings.
It can also be gathered from the modelling that the construction activities will not cause the levels to be excess of the NO_x ecosystems MKN of 30$\mu g/m^3$ as background concentrations in rural areas are not likely to be such that the contribution of 8$\mu g/m^3$ will spur the approach of 30$\mu g/m^3$ (IVL, 2005).

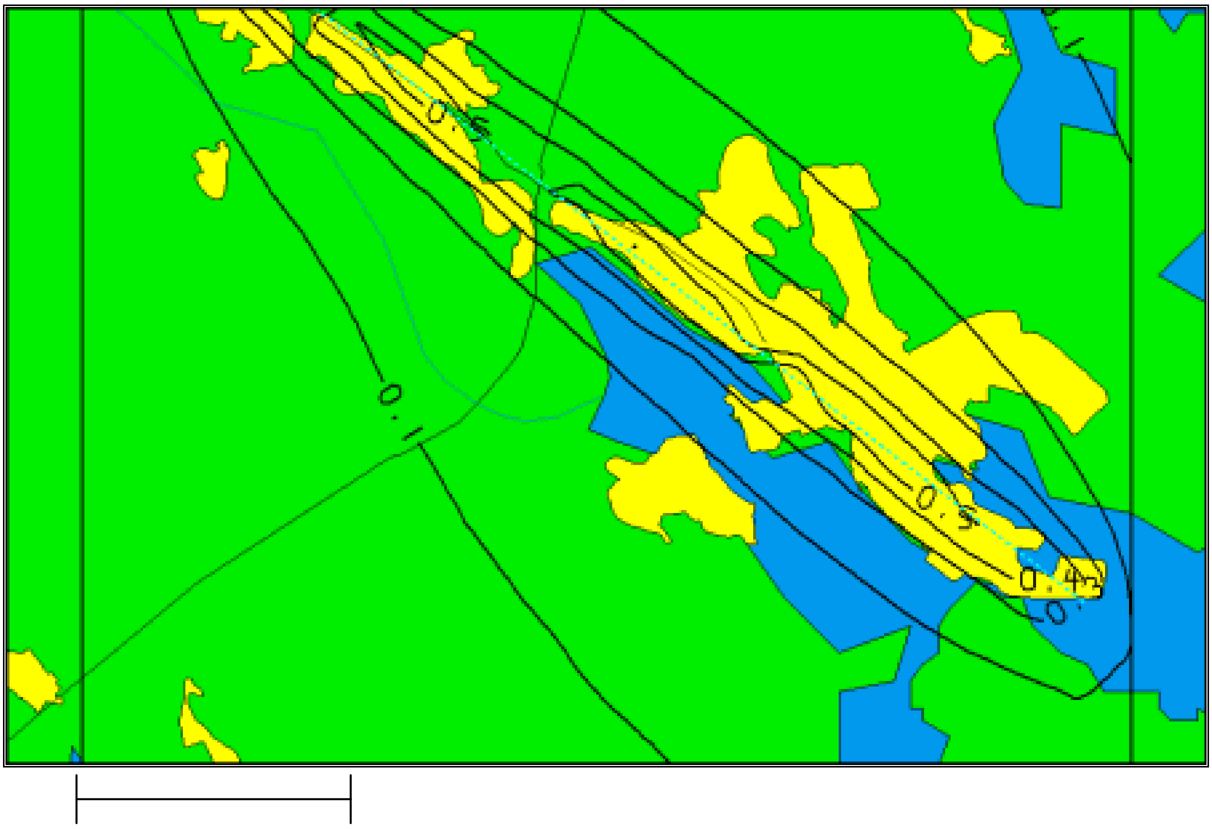
§ 3.2.1.2 PM10

Emissions of particulate matter are generated by all combustion processes including space heating, energy production, automobile exhaust etc. Primary particulate matter can be generated during industrial processes, as dust from roadways, from forest fires etc. Biological particulate matter may also exist in the form of particulates from leaf litter, pollen and micro-organisms (Brimblecombe, 1986). Particulate may also occur as a secondary pollutant resulting from atmospheric reactions involving other primary pollutants such as NO_x and SO_2. The levels of particulate matter in air are highly dependant on weather conditions such as wind intensity and precipitation. Particulate matter may be described in various categories depending on size speciation of particle but the following analysis will only be concerned with PM10.

PM10 was input into the model SMHI 2.1 as an optional parameter and supported by a background concentration of 18, 7µg/m^3. As the values for Piteå and Luleå are winter half year average concentration values, they are likely higher than an average concentration over the whole year. It is likely that the concentrations existing in Skellefteå are similar to those in Piteå or Luleå.

The following figure illustrates the contribution that the terracing activities will have on the annual average PM10 concentration on the high alternative course of the construction assuming a background concentration of 0µg/m^3. Each isoline constitutes a change of 0,1µg/m^3.

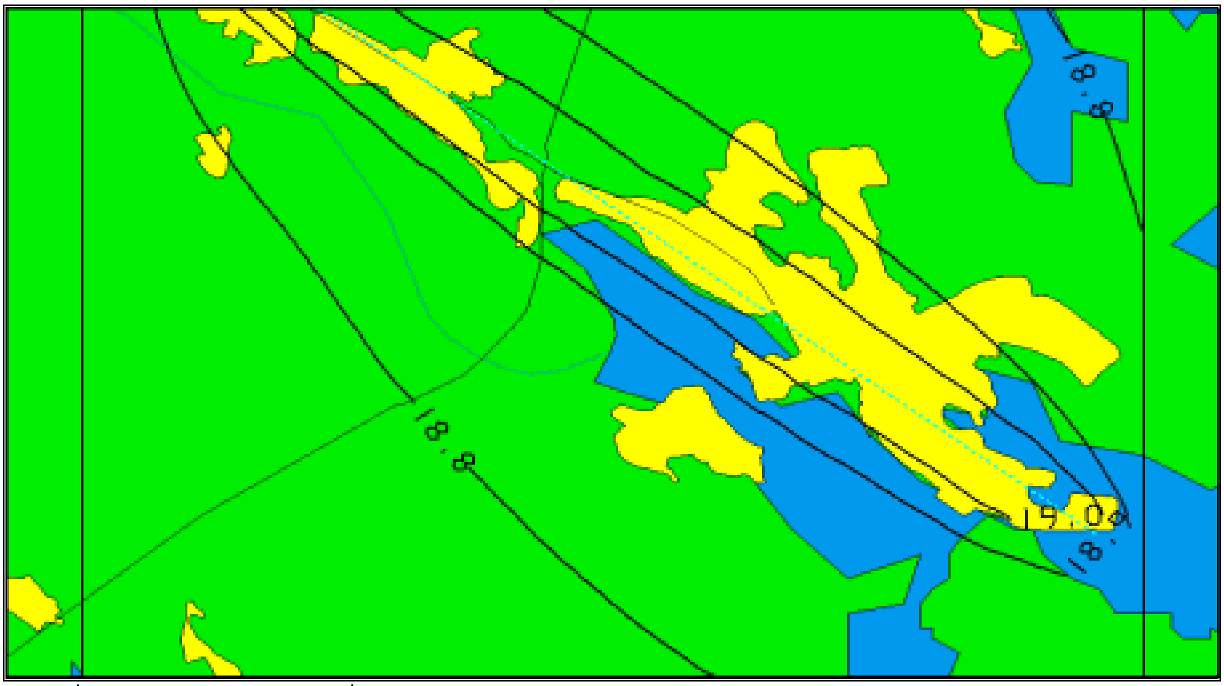
Figure 16: PM10 Annual Average (µg /m^3) Assuming Background of 0 µg /m^3



4 cm =5km

The following figure provides an illustration of the influence the terracing activities will have during the peak activity year on the annual average concentration assuming a background concentration of 18,7µg /m^3 along the high alternative course.

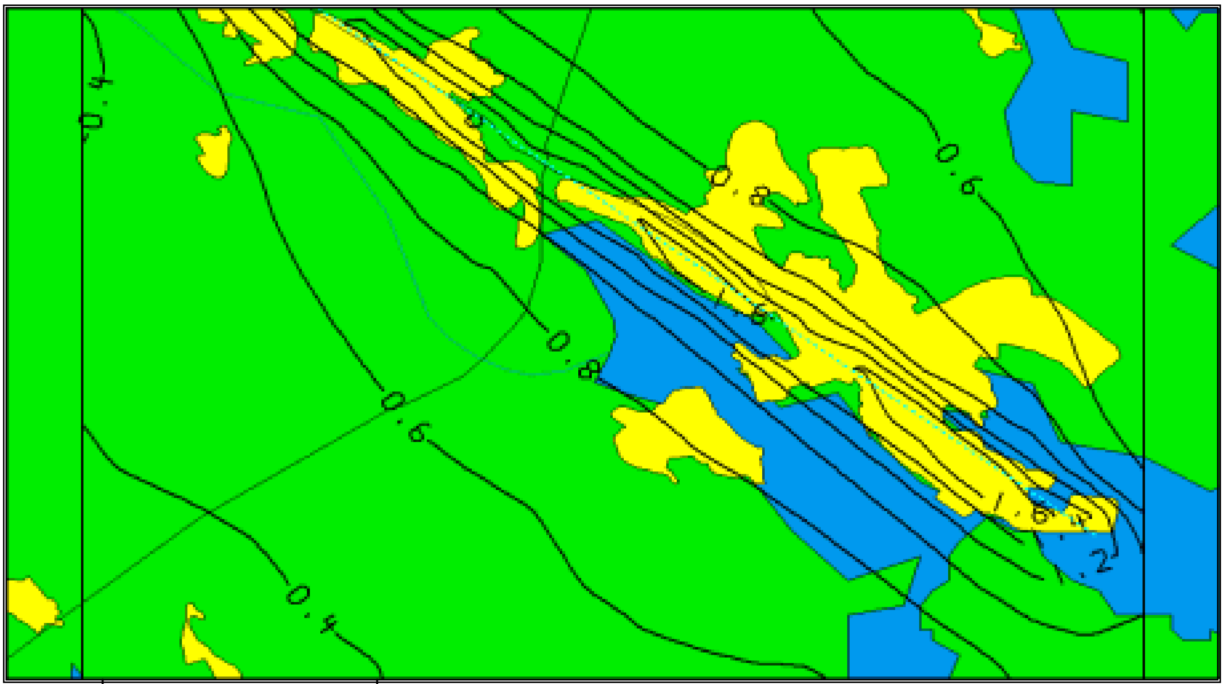
Figure 17: PM10 Annual Average (µg /m^3) Assuming Background of 18,7 µg /m^3



4 cm = 5km

Figure 18 provides an illustration of what value 98% of daily average concentrations. Each isoline represents a difference in PM10 concentration of 0, 2 $\mu g/m^3$, and as can be seen below the peak concentration is 1, 6$\mu g/m^3$ over the background concentration input into the model.

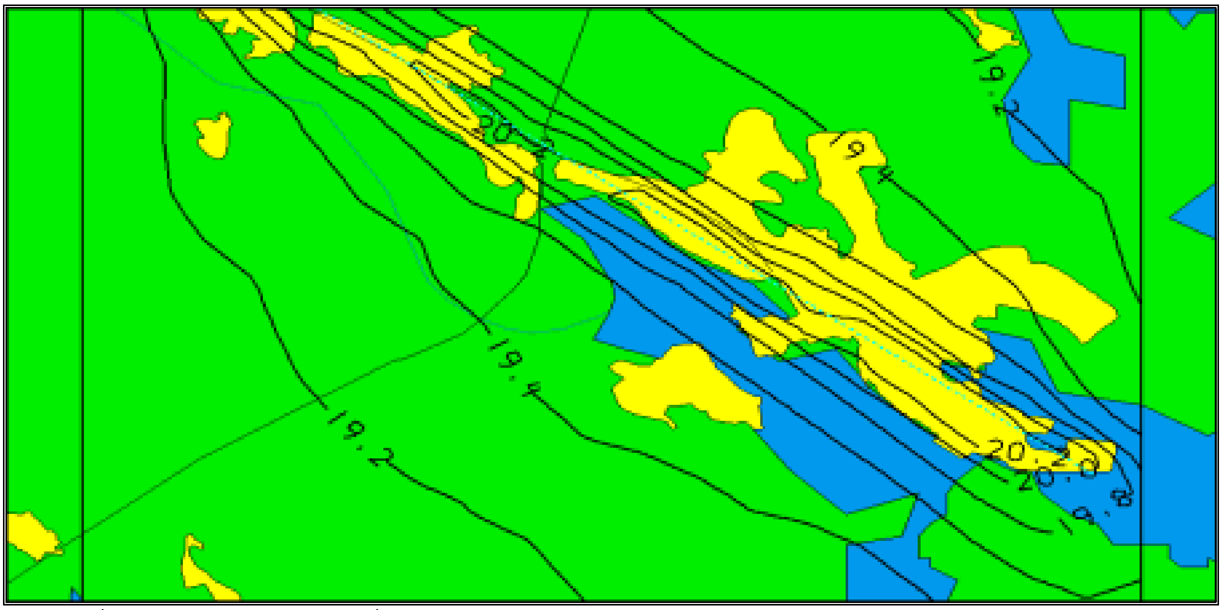
Figure 18: PM10 98 % Percentile Value ($\mu g/m^3$) Assuming Background of 0$\mu g/m^3$



4 cm = 5km

The following is a description of the 98$^{\%}$ percentile daily average value when a background concentration of 18, 7$\mu g/m^3$ is incorporated.

Figure 19: PM10 98% Percentile Value ($\mu g/m^3$) Assuming Background of 18.7$\mu g/m^3$



4 cm = 5km

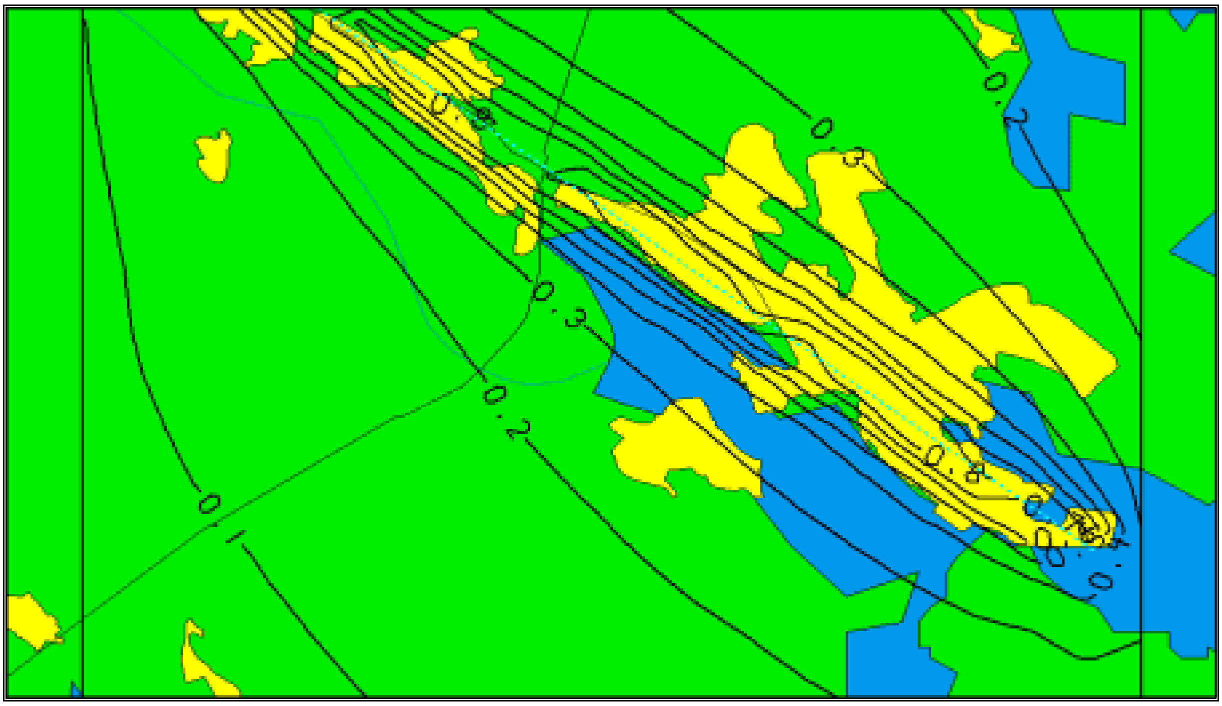
§ 3.2.1.3 Hydrocarbons

Emissions of volatile organic compounds / hydrocarbons may result from crank case exhaust, equipment leaks in machinery or the incomplete combustion of fossil fuels. The scope of this investigation is confined to the volatile organic compounds originating from the incomplete combustion of fossil fuels. Methane is often separated from other volatile organic compounds because it is also an important greenhouse gas and the result is a reading for non methane volatile organic compounds (NMVOC) and methane.

Information on the background concentration of hydrocarbons and carbon monoxide were not readily available for all communities so influence on the background concentration was determined by operating the model using an assumed background concentration of 0$\mu g/m^3$. The increases to be expected are useful in supporting the expectation that the adverse influence on hydrocarbon and carbon monoxide values in the host communities will be minimal. An MKN exists for benzene as a yearly average < 5,0 $\mu g/m^3$ but it is certainly not of concern as all communities in Sweden with the exception of Helsingborg lie below 3.0 $\mu g/m^3$ with most lying between 1 and 2$\mu g/m^3$. Comparison to the MKN's for hydrocarbons will not be completed at this time due to the absence of information on the proportion of benzene contained in the hydrocarbon and non methane volatile organic compounds calculations.

The figure presented below exhibits the influence of the peak year of construction on the annual average concentration of hydrocarbons. Each isoline represents a change of 0.1$\mu g/m^3$ in the annual average concentration for hydrocarbons. The increase resultant from the peak construction year ranges between 0 and 0.8$\mu g/m^3$.

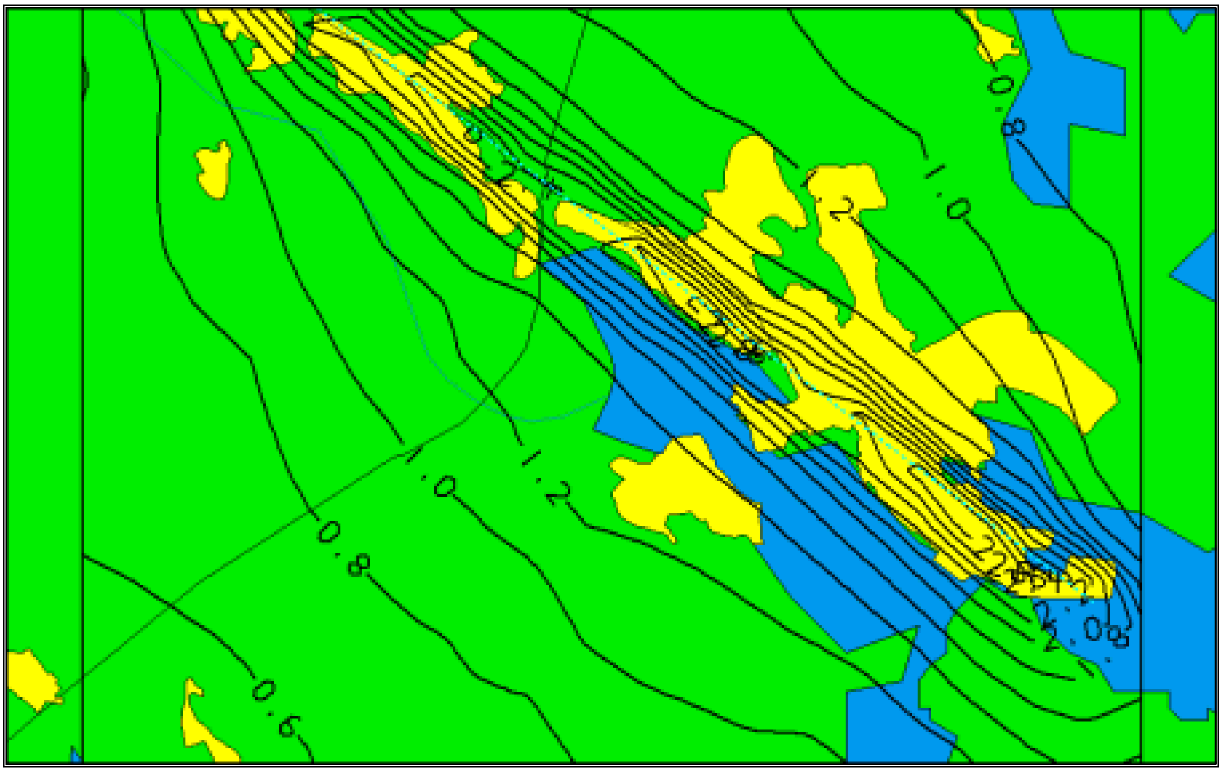
Figure 20: HC Annual Average ($\mu g/m^3$) Assuming a Background of 0 $\mu g/m^3$



4 cm = 5km

The figure below presents the influence of the construction activities on the daily average concentration of HC which 98% of days will lie at or below. Each isoline represents a change of 0, 2μg/m^3, in the concentration of daily average HC. As can be seen below, the 98th percentile daily average will be increased between 0 and 2, 4 μg/m^3 during the peak year of construction activities.

Figure 21: High Alternative HC 98% Percentile for Daily Mean Values (μg/m^3)



4 cm = 5km

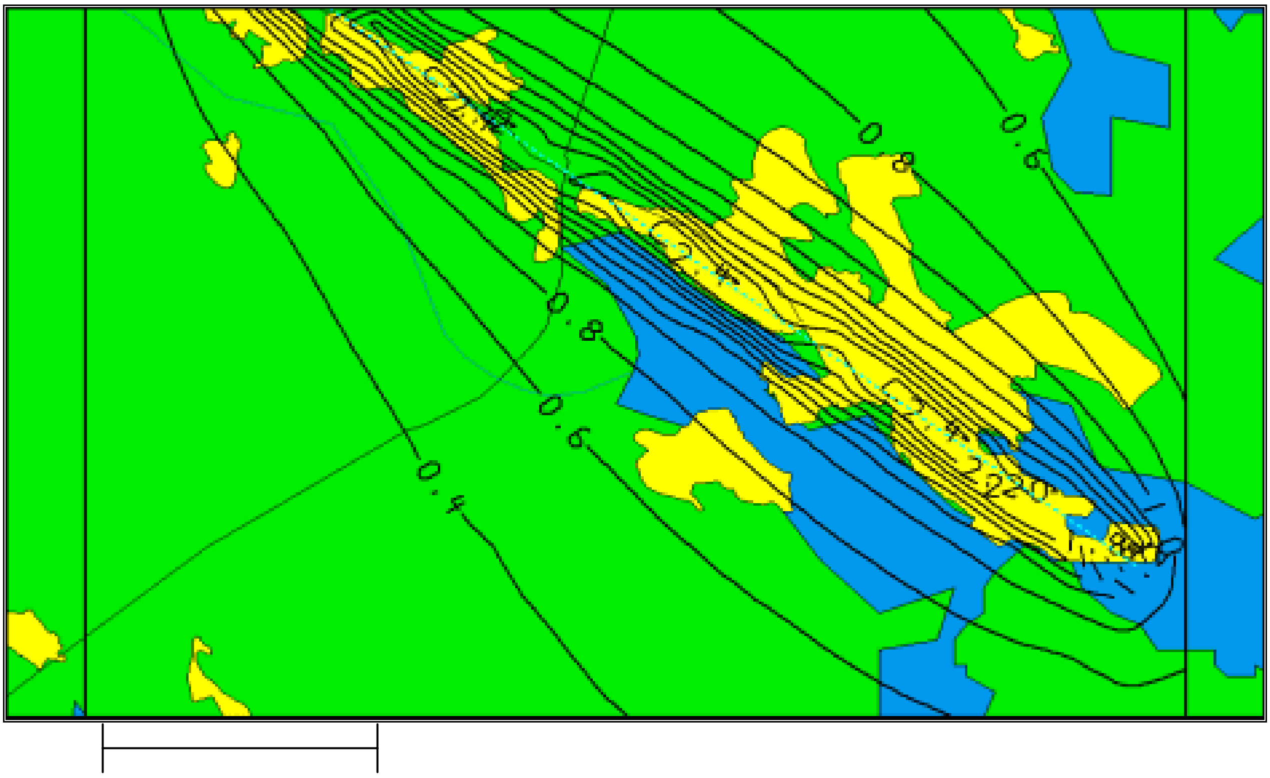
§ 3.2.1.4 CO

Carbon monoxide (CO) is generated by the incomplete combustion of carbon containing materials including fossil fuels. The primary health concern associated with CO is its effect on the bloodstream. CO is absorbed into the bloodstream through the lungs and forms carboxy haemoglobin, inhibiting the proper function of haemoglobin and hampering the ability of the circulatory system to distribute oxygen throughout the body (Environment Canada, 2006). The health threats associated with ambient CO is of exceptional concern for individuals suffering from cardiovascular illness. Minor symptoms include dizziness, fatigue and inability to complete complex tasks.

The MKN for carbon monoxide is that rolling 8 hour means of CO should not exceed $10 mg/m^3$. The highest rolling 8 hour mean recorded on a main arterial road in central Stockholm, Hornsgatan was $2\ mg/m^3$, while the yearly background average on Hornsgatan was $0{,}2\ mg/m^3$(IVL, 2005). Accordingly, Swedish urban areas such as Luleå, Piteå and Skellefteå are not likely to have any concern with even remotely approaching the MKN for CO.

As can be seen in the figure below, the influence of the peak construction activities is to increase the annual average between 0 and $2.4 \mu g/m^3$. Each isoline represents a change of $0.3 \mu g/m^3$ in the annual concentration of CO.

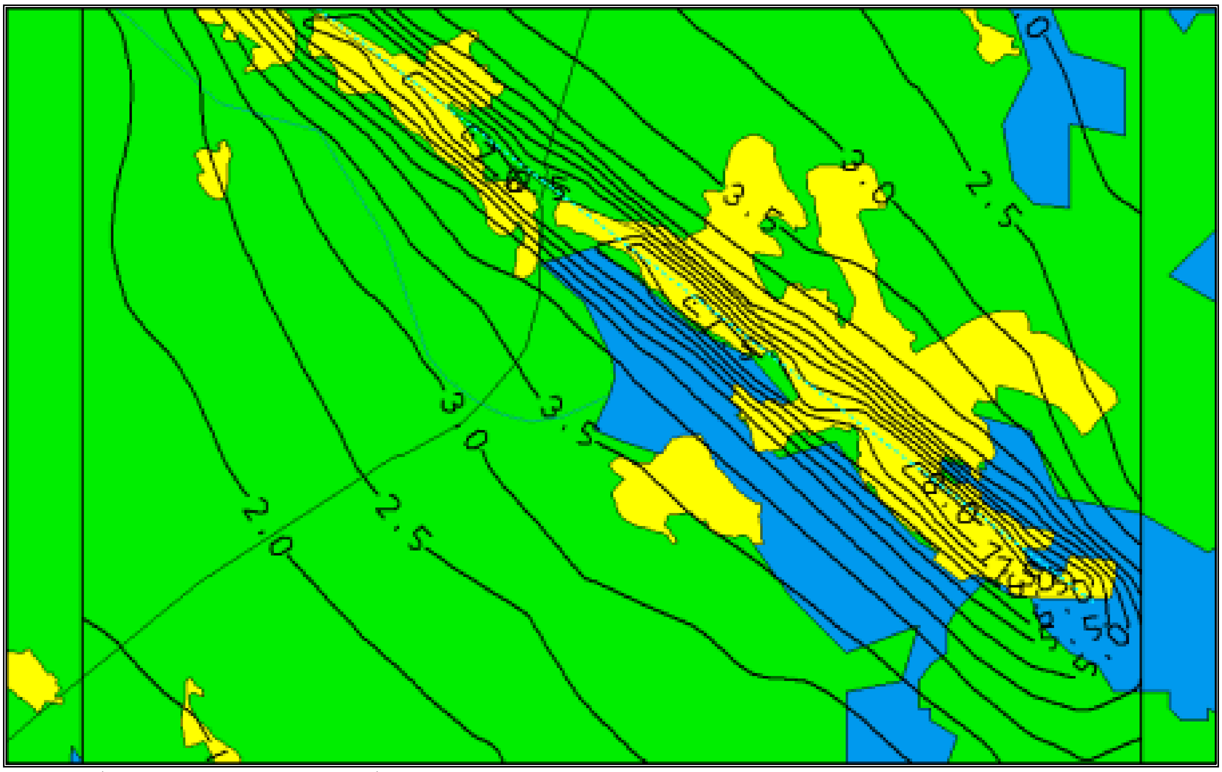
Figure 22: CO Annual Average ($\mu g/m^3$) with a Background Concentration of 0 ($\mu g/m^3$)



4 cm = 5km

The figure below presents the influence of the construction activities on the daily average concentration of CO which 98% of days will lie at or below. Each isoline represents a change of $0.5 \mu g/m^3$, in the concentration of daily average CO. As can be seen below, the 98th percentile daily average will be increased between 0 and 7, 5 µg/m^3 during the peak year of construction activities.

Figure 23: CO 98% Percentile Value (µg/m^3) with a Background Concentration of 0µg/m^3



4 cm = 5km

§ 3.2.1.5 Discussion

It is predicted that the current air quality standards, as with many pollution regulation initiatives are not the final state of the air quality standards and are simply a step towards the reduction of air pollution in a step wise reduction program. The emissions caused by the peak construction activities do not cause the emissions to approach the current MKN's. However, the environmental objectives that have been set out by Naturvårdsverket present a much benchmark that is one half of the currently enforced regulations. The highest level of NO_2 influenced by the construction activities is 20, 14 µg/m^3, which corresponds to an environmental objective for the annual mean of less than 20 µg/m^3 by 2010. It is predicted that this value is slightly higher but less than 24, 18 µg/m^3. The highest level of PM10 influenced by the construction activities is 19µg/m^3 which corresponds to an environmental objective for the annual mean of less than 20µg/m^3.

§ 3.3 Material Transportation Related Emissions

The transportation of construction materials to the construction site will contribute to the air pollution generated along the transportation arteries of Sweden and Northern Europe. The following table provides a summary of the air pollution emissions associated with the transportation of materials needed for construction to the construction site. When considering the effect of the below emissions on human health and the environment one must also understand that the emissions are spread over line sources varying between < 100km for macadam up to approximately 2500km for the rails. Emissions will also be distributed throughout the six year construction period.

Table 23: Summary of Emissions Due to Construction Material Transportation

Pollutant	Norrbotniabanan (tonnes)
CO (luft)	3,79
CO_2, biogent (luft)	287,18
CO_2, fossilt (luft)	4 158,66
HC (luft)	3,52
N_2O (luft)	0,01
NO_x (luft)	32,62
Partiklar (luft)	0,71
SO_2 (luft)	1,42
Cd (aq.)	0,00

§ 3.4 Operation and Maintenance Emissions

The operation and maintenance of the railway will require 384 360MJ of gasoline and 1 256 400MJ of diesel fuel for the operation and maintenance of the 270 kilometres of the Norrbotniabanan (IVL B1526, 2003) annually. The emissions that will be generated directly from the consumption of this fuel over the 60 year life span of the Norrbotniabanan are displayed in the following table.

Table 24: Total Operation and Maintenance Emissions (IVL B1526, 2003)

Species	Emissions (tonnes)
NO_x (luft)	152,58
HC (luft)	8,75
SO_2 (luft)	1,16
CO_2, fossilt (luft)	32 989,94

§ 3.5 Emissions Balance over Time and Recovery Time

Using the emissions recovery rates associated with the projected changes to the transportation system in Northern Sweden resulting from the operation of the Norrbotniabanan, the time required to recover the emissions that will result from the construction period have been calculated and are presented below.

As can be seen below the recovery rate per year during operation is 92% of the annual direct emissions of CO_2 and approximately 55% of the annual NO_x emissions calculated for the construction activities.

Table 25: Recovery Times (years)

Species	Total Construction Emissions	Operation and Maintenance	Annual Reductions	Recovery Time	Net Reductions Over Lifespan
	Tonnes	Tonnes/Year		Years	Tonnes
CO	813,74	-	-	-	-
NMVOC	300,38	0,15	28,94	10,82	1 727,93
NO_x	2 612,22	2,54	237,58	11,11	11 489,95
Partiklar	187,38	-	2,91	64,38	-12,75
NH_3	0,44	-	-	-	-
SO_2	0,35	0,02	6,30	0,06	376,61
N_2O	77,60	-	-	-	-
CH_4	11,09	-	-	-	-
CO_2	153 954,18	549,83	23 589,17	6,68	1 228 405,90
Total CO_2e	178 242,94	-	-	-	-

Figure 24: NO_x Balance throughout Construction and Operation

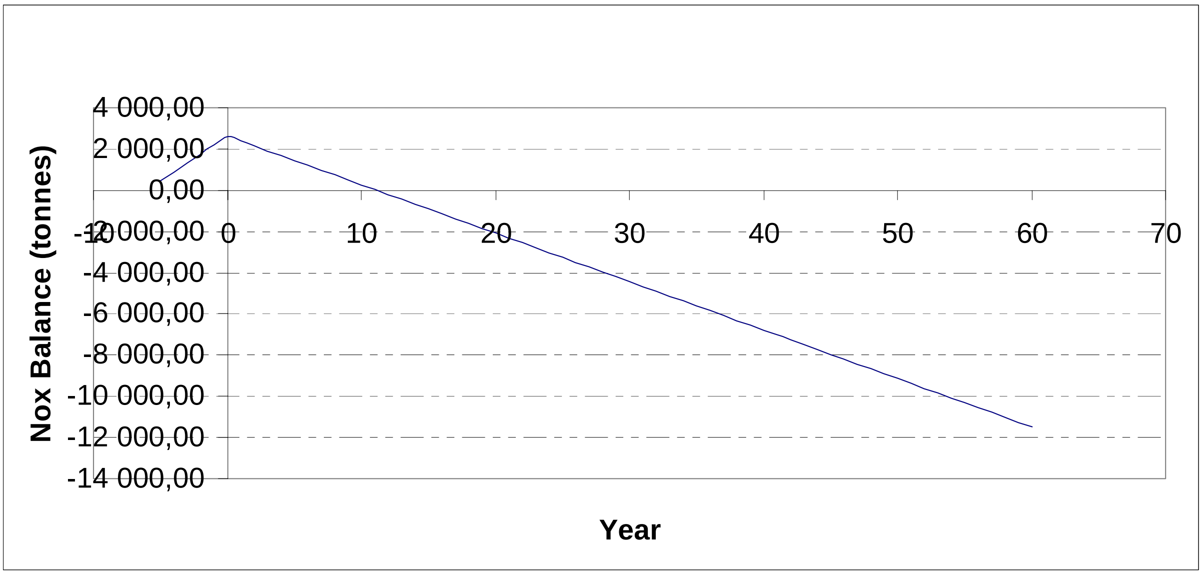
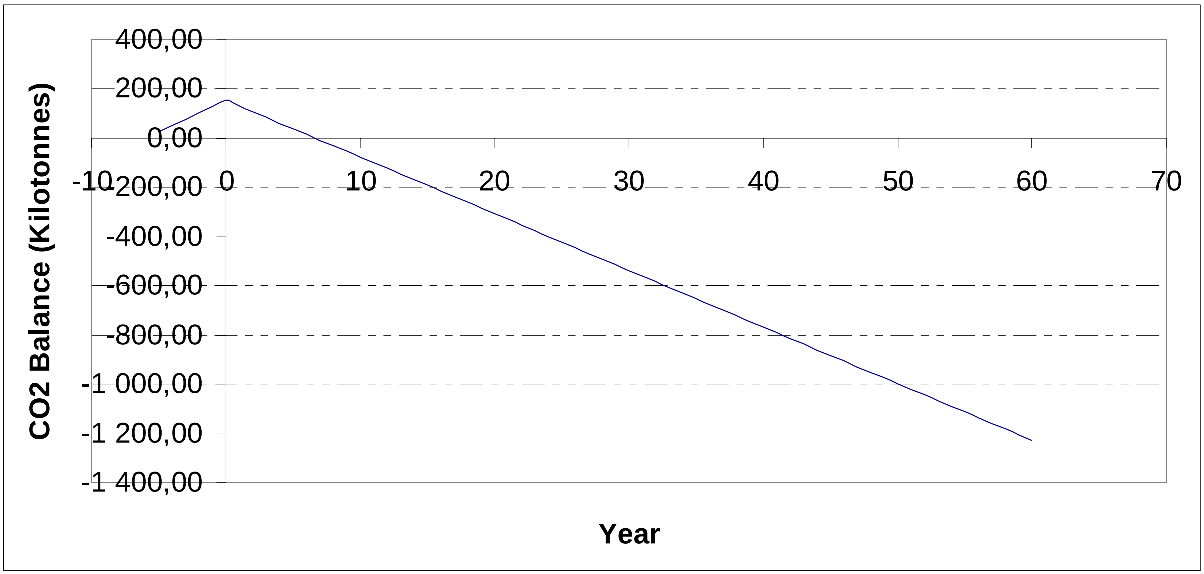


Figure 25: CO_2 Balance throughout Construction and Operation



In the currently available air pollution reductions based on transportation system projections outlined in the "2003 Regerings Uppdaterad för Norrbotniabanan," there was no mention of emissions reduction due to the transfer of person traffic from either bus or flight to rail. This is however not considered to be absolutely accurate: The bus mode of transportation would be in direct competition with train for commuter traffic between the cities, and thus the train would likely accept person traffic from bus upon operation.

In comparison with the Botniabanan calculations of recovery time, it is quite evident that the PM10 annual reductions have been underestimated in this investigation. If the operation of Botniabanan has been calculated to reduce particulate emissions by 12 tonnes / year, one must presume that value of 3, 79 presented above have underestimated the projected reductions. The emission factor used in the calculation of reduction particulate emissions due to changes in personal automobile activity are based on emissions for vehicles projected to be in operation by 2020 and founded on the assumption that by that time, all vehicles will have pollution control mechanisms which will reduce particulate emissions to negligible levels (Degerman, 2006).

The following table illustrates some striking differences between the findings of the Botniabanan prognosis of 2003 and the projections presented above. Most interesting are the comparison of the annual reductions for each railway and the relative increase of some pollutant emissions over a similar operation time. It has been stated that the operation hours were underestimated in the Botniabanan report. As can be seen below, the change in operation time is comparable in percentage increase to the distance, and considering the underestimation for the hours required for completion of the Botniabanan, one would expect a relative increase in the values for the completion of the Norrbotniabanan. It is suspected that the simplified terracing of the Norrbotniabanan due to reduced topographic variance and the demands of terracing through the Botniabanan course negates the possibility of any significant underestimation of the Norrbotniabanan based on a direct comparison of the two projects. Also interesting is the decrease in emissions reductions from the operation of the Norrbotniabanan in comparison to the operation of the Botniabanan. The origin of the annual reductions difference is expected to stem from the assumptions made in each of the prognoses. It is possible that the assumptions could change significantly in revisions or alternately stay the same. The emissions of CO2, PM10 and hydrocarbons appear to increase greater than the increase in operation time between the two projects. The relative increase in pollutant emission resulting from a similar operation period are likely to be the result of the incorporation of more fuel intensive machinery such as stone crushers and drilling units and small changes in the emissions factors used. The difference between the Botniabanan and Norrbotniabanan recovery times are considered to be a cumulative result of changes in both the annual reductions and total construction emissions. There is projected to be an updated transportation prognosis completed in early 2007 and the recovery time calculations should be updated as this information becomes available.

Table 26: Comparison to Botniabanan Prognosis

Parameter		**Botniabanan (tonnes)**	**Norrbotniabanan (tonnes)**	**% of Botniabanan**
Project	Distance	190km	270km	*142%*
	Operation Time	2 000 000hrs	2 776 625hrs	*139%*
NO_x	Construction Emissions	1 770,00	2 617,34	*148%*
	Annual Reductions	365	237,58	*65%*
	Recovery Time	4,8	10,82	*225%*
HC/NMVOC	Construction Emissions	195	300,92	*154%*
	Annual Reductions	28	28,94	*103%*
	Recovery Time	7	11,11	*159%*
CO_2	Construction Emissions	89 000	154 018,80	*173%*
	Annual Reductions	53 900	23 589,17	*44%*
	Recovery Time	1,7	6,62	*389%*
PM10	Construction Emissions	70	187,75	*268%*
	Annual Reductions	12	2,91	*24%*
	Recovery Time	5,8	64,38	*1110%*

§ 4 Conclusion

The construction of the Norrbotniabanan will cause the generation of air pollutants and greenhouse gases in the short term. However, these emissions will not cause the levels of key air pollutants to rise to levels that will be acutely harmful to human health and the environment in the urban communities along the projected course of construction. The environmental quality norms (MKN) for particulate, oxides of nitrogen, hydrocarbons, and carbon dioxide will not be exceeded due to Norrbotniabanan construction emissions.

Modelling has only been completed for Luleå. However, it is clear from the modelling completed that the environmental quality norms will not be approached in Luleå and thus likely will not be approached in either Piteå or Skellefteå. Additional modelling for the other two urban communities along the railway course would not contribute to the quality of this analysis at this time.

Over the projected six year building period, construction activities will generate 815,05 tonnes of carbon monoxide, 300,92 tonnes of non methane volatile organic compounds, 2 617,34 tonnes of oxides of nitrogen, 187,75 tonnes of PM10, 0,44 tonnes of ammonia, 0,35 tonnes of sulphur dioxide, 77,74 tonnes of nitrous oxide, 11,11 tonnes of methane, 154 018,80 tonnes of carbon dioxide and 178 352,27 tonnes of carbon dioxide equivalents. During the peak phase of construction, terracing, the maximum increase in the annual average of NOx will be 8, 0 $\mu g/m^3$, of CO will be 2, 4 $\mu g/m^3$, of PM10 will be 0,5 $\mu g/m^3$ and of hydrocarbons will be 0,8$\mu g/m^3$.

Using currently available information, the total construction emissions are expected to be recovered within 12 years of operation with the exception of particulate matter whose recovery rate is currently subject to significant scrutiny due to variance from usual association with other pollutants generated by fossil fuel combustion as well as the present absence of bus transportation from emissions recovery data. The emissions of carbon dioxide generated during the construction of the Norrbotniabanan are expected to be recovered within seven years of operation. In coming months, revised values for the emissions reductions due to the operation of the Norrbotniabanan may show a faster recovery of emissions.

The current analysis does not afford for the special case of the construction of an exceptionally difficult bridge or tunnel in which machinery will be relatively stationary over a longer period. The construction also does not include the possibility of cumulative effects of additional point sources that may occur in specific points in space and time such as the E4 in Skellefteå and the pulp and paper mills in both Piteå and Skellefteå.

Although the current environmental quality norms will not be exceeded, the future objectives that have been set out by Naturvårdsverket will likely be exceeded. Measures should be taken to minimize the air emissions during construction in order to assist the achievement of the potentially lower air quality standards during the real construction period.

§ 5 Recommendations

In future investigations, significant improvements to the quality of results may be realised by the improvement of the information on which the analysis is founded. In order to complete a better representation of the air pollution expected from the construction of the Norrbotniabanan as well as other construction projects in the coming future, enhancements need to be made to the quality and availability of input data such as the expected number of machines implicated in the construction of a railway, the operation time during construction, and the singular definition of the construction course through the three communities.

The information for the reduction due to the changes to the transportation system should also be revised. It is clear that the current numbers underestimate the reduction potential of the Norrbotniabanan. For example, there are currently no reductions mentioned for the changes of person traffic from bus to rail. This is incorrect, especially between cities in which there is a significant potential for commuting such as Piteå and Luleå as well as the fact that the current bus traffic is considerably active.

The current calculations do not take into consideration the possibility of a localised event in which the construction concentrates a large number of machines in a small area. Additional attention could be devoted to inspect the possibility of a localized and concentrated construction activity such as a tunnel or a bridge. Were more activity data available for the number of machines used in the terracing of various contexts, it may be possible to discern the relationship between topography and air pollution but at this point, the information available did not permit the generation of such a relationship. The limited work on analyzing the potential relationship

Although the findings of this investigation have concluded that there is minimal risk of exceeding the MKN's during the construction activities, all available measures should be taken to minimize the generation of air pollution.

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Personal Communication

Wolf-Watz, Camilla, Botniabanan AB (0660-29 48 76)

Uppenburg, Stefan, Botniabanan AB (0660-29 58 63)

Nilsson-Suiki, Anders, Banverket Norra Banregionen Underhåll Sektionen (070-524 94 74)

Degerman, Henry, Banverket Norra Banregionen, Norrbotniabanan Project (0920-351 13)

Bengtén, Mats, Banverket Norra Banregionen, Tekniksektionen

Accompanying Files

The following files accompany and support the information presented in this investigation.

"NBB_Time_Balance.xls" the worksheet used to analyze the relationship between total emissions and the pollution reductions due to the operation of the Norrbotniabanan. (MS-Excel Work Book) Ross Phillips

"NBB_Indirect_Material_Transport.xls" is the worksheet used to calculate the emissions associated with the transportation of materials to the construction site. (MS-Excel Work Book) Ross Phillips

"NBB_Peak_Construction_Emissions_Rates.xls" is the worksheet used to model the peak operation of machinery and accordingly the peak emissions rates associated with construction activities. (MS-Excel Work Book) Ross Phillips

"NBB_Terracing_Emissions.xls" is the worksheet used to calculate the emissions associated with the terracing or foundation work included in the construction of the Norrbotniabanan. (MS-Excel Work Book) Ross Phillips

Appendix I: Air Quality and Standards

§ AI.1 Environmental Quality Norms

Sweden currently employs an ordinance expressing environmental quality norms that must be abided by for nitrogen dioxide, sulphur dioxide, particulate matter, lead, carbon monoxide, and particulate matter in order to maintain human and environmental health (Naturvardsverket Homesite, 2006). Communities are thus required to check compliance through estimates or measurements for each of the contaminants.

Table AI.1: Summary of Current Air Quality Standards

Substance	Concentration not to be exceeded
Nitrogen oxides (NO2 and NOx)	
Hour (NO2) [1]	90 µg/m3 (2006)
24 h (NO2) [2]	60 µg/m3 (2006)
Year (NO2)	40 µg/m3 (2006)
Year (NOx, eco systems)	30 µg/m3 (2001)
Sulphur dioxide (SO2)	
Hour [1]	200 µg/m3 (2001)
24 h [2]	100 µg/m3 (2001)
Year (eco systems)	20 µg/m3 (2001)
Winter half-year (eco systems)	20 µg/m3 (2001)
Carbon monoxide (CO)	
24 h [3]	10 mg/m3 (2005)
Lead	
Year	0,5 µg/m3 (2001)
Benzene	
Year	5 µg/m3 (2010)
Particulate Matter (PM10)	
24 h [4]	50 µg/m3 (2005)
Year	40 µg/m3 (2005)
Ozone	
8 h mean [3]	120 µg/m3 (2010)
Summer half-year (Apr-Sep) [5]	18 000 AOT40 (2010), 6 000 AOT40 (2020)

1) To be exceeded not more than 175 times per year (98 percentile, hr)

2) To be exceeded not more than seven times per year (98 percentile, 24 hr)

3) Rolling eight hour mean

4) To be exceeded not more than 35 times per year (90 percentile, 24-hr)

5) AOT 40 (expressed as ug/m3 x hr) calculated as the sum of differences of hour mean concentrations over 80 ug/m3 (040ppb) and every day during the season 1 May to 31 July each year.

§ AI.2: Environmental Objectives (Miljömål)

Naturvårdsverket has also published levels associated with national environmental objectives (miljömål). According to the interim targets for clean air "A level of nitrogen dioxide of 60µg/m^3 as an hourly mean and of 20 µg/m^3 as an annual mean will largely not be exceeded" and "A level of particles (PM10) of 35 µg/m^3 as a daily mean and 20µg/m^3 as an annual mean will not be exceeded by 2010." (Naturvårdsverket, 2006) The daily means may not be exceeded for more than 37 days in one year." Accordingly, special attention will also be provided in comparison to the projected goals to be achieved for air quality in Sweden. Environmental quality objectives have also been published for sulphur dioxide, ground level ozone, volatile organic compounds, benzo(a)pyrene and particulate matter with a mean diameter less than 2.5 micrometers.

§ A.I.3: Current Air Quality

Norrland is conventionally synonymous with fresh and pristine air. This however does not preclude the existence of airborne compounds with adverse affects on human health and the environment in urban settings nor the necessity to preserve the environmental health of Norrland, both human and otherwise. The following section will provide a brief examination of the urban air quality in Luleå, Piteå and Skellefteå, including current baseline levels to be accepted and used during this report. Umeå has not been included in this investigation as the construction of the Norrbotniabanan will commence north of the built up area of Umeå.

During the winter months, polar subsidence inversions create a meteorological ceiling above the ground, trapping anthropogenic emissions close to the ground and disabling the diffusion of concentrations further up and away from urban areas. In urban areas, peak contaminant concentration events generally coincide with cold weather events in which the inversions are strongest and levels of fuel combustion are elevated (Umeå Kommun, 2005). The influence of winter subsidence inversion conditions results in the winter months being the time of year when air pollutant concentrations are highest and of greatest concern. Exceptionally high concentrations of air contaminants often occur in association with relatively low temperature events when the inversions effects are most pronounced and other factors such as increased idling of motor vehicles and heating increase combustion related emissions (Umeå Kommun, 2005).

The values presented are for measurement periods during 2001-2002 for Luleå, 2004-2005 for Piteå and 2003-2004 for Skellefteå in order to establish an illustration of the background air quality using the best available supporting information for each of the communities. Presented below are the values collected for the particulate matter in the three communities presented as an average over their respective measurement period. Due to the inconsistency of the measurement periods some account must be given for the variation of the values. As with the NOx concentrations, the Skellefteå data is considered exceptionally high. The measurement period for Skellefteå's PM10 measurements, was March and April of 2004 the values are highly influenced by the formation and mobilization of PM10 in the form of dust after snow melt before the motorway adjacent to the measurement site has been cleaned. This information has been included as an appendix over concern that the presentation of such information would risk misinterpretation by readers.

§ AI.3.1 Luleå population 45, 036

Luleå is not currently a participant in the URBAN air quality monitoring program. The Luleå Kommun Miljökontoret has a real time display of air quality levels in the community. In 2001-2002 an investigation spanning the winter months to establish levels for background concentrations of NOx and PM10 and attempt to discern a reproducible relationship between NOx and NO2 concentrations in Luleå. The NOx measurements were completed at eight sites across the built up area of Luleå. The NOx concentration accepted as a valid background concentration for the area of the line source is 60µg/m^3. The NOx concentrations for the 2001-2002 winter half year for the Kungsgatan site (located on the edge of the centrum) was 56 µg/m^3. As the concentrations increase up to 76µg/m^3 as measurements are taken in the higherm PM10 readings were collected from one location , the Kungsgatan monitoring site located at the edge of the centrum which may be considered an urban background site. (Luleå Kommun Miljökontoret).

§ AI.3.2 Piteå population 22, 152

As a participant in the IVL Svenska Miljö Institutet URBAN air quality monitoring program, the levels of NO_2 are measured at seven different locations throughout the city and concentrations of PM10 are also monitored at two sites, one of which is named Bertnäs and serves as the urban background. Piteå uses an accredited analysis method that uses SWEDAC methodology (Piteå Kommun, 2005).

§ AI.3.3 Skellefteå population 34, 737

The information currently available for the historic air quality in Skellefteå is not as complete as the information available for Piteå and Luleå. PM10 measurements have been completed for periods between one and two months during the spring of 2003, 2004 and 2006. The available information is subject to weakness in that the measurement activities are limited to short periods whose extrapolation to a yearly average is questionable, especially due to the evolution of abnormally high levels of PM10 between snowmelt and the cleaning of the motorway. NO2 measurements have been completed for a period of 2003-12-01 until 2004-11 for a western and eastern route of Kanalgatan – a major roadway. NO2 measurements have also been completed for a northern and southern route of the E4 passing through Skellefteå. In conversation with Skellefteå Kommune, it was established that Skellefteå had declared their exceedance of the MKN's to Naturvårdsverket. However, upon review of the submitted information, Naturvårdsverket found flaws in the measurement and presentation of the air quality and accordingly concluded that Skellefteå was not currently exceeding the MKN's for air quality. The daily average PM10 results over the different measurement periods completed during 2003, 2004 and 2006 vary significantly dependant upon location and measurement period. The average concentrations over each of the periods are 17,1 µg/m^3, 40,5 µg/m^3, and 50,1 µg/m^3 respectively. The measurement site for 2003 and 2004 was located on Kanalgatan, an arterial roadway and carried out during May – June, 2003. April-May, 2004. Due to the uncertainty in the measurement information presented by Skellefteå Kommun, it will be assumed that the background concentration is less than or equal to those documented in Luleå and therefore the modelling of for Luleå should be a sufficient description of Skellefteå also.

§ A.I.4 Summary of Background Air Quality

The values that have been recorded for the Piteå, Skellefteå and Luleå are expected to be the highest in their respective communities while Skellefteå are not considered to be reliable but have been included.

The following figures below present the background concentrations of NO2 and PM10 in each of the three urban settings. Please note that not all values are generated from similar collection points nor during similar time periods.

Figure AI.1: Annual average NO2 Measurements for Subject Communities

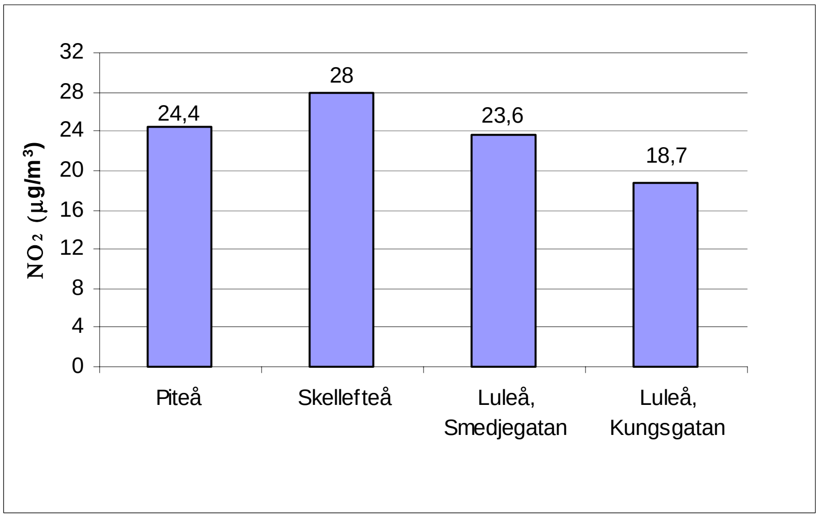
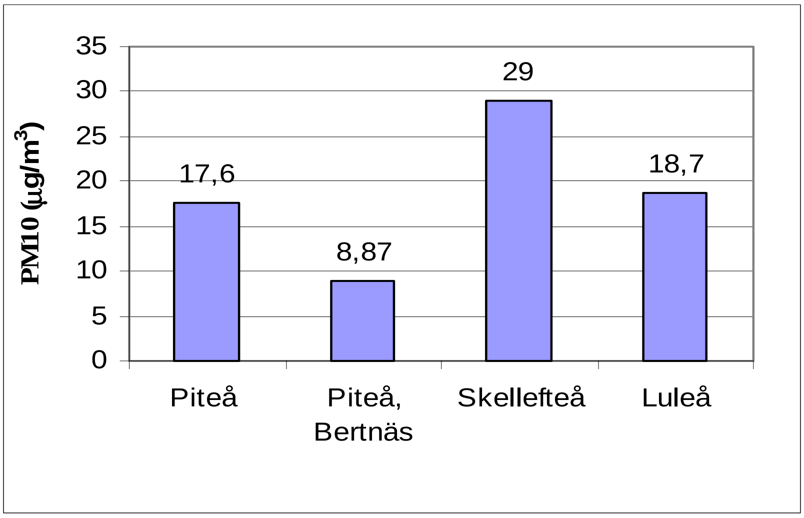


Figure AI.2: Measured PM10 Levels in Subject Communities



The table presented below exhibits the relationship between NOx and NO2 concentrations according to the measurements completed during 2001/2002. For the six measurement stations above 38µg/m^3, the average ratio of NO2 to NOx is 0, 31.

Table A1: NOx and NO2 Relationship (µg/m^3)

Measurement Point	Average Nox	Average NO2
Badhuset	61	18,7
Kungsgatan	56	22,3
Loet	67	20,7
Smedjegatan	76	23,6
Södra Hamnleden	67	16
Rådstugatan	56	15,2
Stadshustaket	22	9,3
Ombergsskolan	38	14

Appendix II: Glossary of English Terms

The following table provides a brief summary of translations of the Swedish words used in this report. In the cases where Swedish words were used, it was not reasonable to replace them outright with their English counterpart.

Tabell AII.1: Translations of Machinery Names

Svenska	Engelska
Bandlastare	Tracked loader
Bandschaktare	Bull dozer
Beläggningsmaskiner	Surfacing Machine
Dumper, ramstydra	Dumper, articulated steering
Grävlastare	Excavation Loader
Grävmaskiner, band < 6.1 ton	Digging Machine, tracked < 6.1 ton
Grävmaskiner, band > 6.1 ton	Digging Machine, tracked > 6.1 ton
Grävmaskiner, hjul	Digging Machine, wheeled
Hjullastare*till jordbr	Wheeled Loader
Mobilkranar < 10 ton cap.	Mobile Crane < 10 ton cap.
Mobilkranar > 10 ton cap.	Mobile Crane > 10 ton cap.
Skidsteers (Kompaktlastare)	Small loader
Teleskoptruck	Telescope truck
Tipptruck	Tip truck
Väghyvlar	Motor grader
Vältar	Roller Compactor
Truck	Large Domestic Truck
Diesel Lok	Diesel Locomotive
Övrigt Banverket	Other Railway Machinery
Dieseltåg	Diesel Train
Lastbil	Truck
Lastbil med släp	Truck and Trailor
Diesellinjelok	Diesel Transport Train
Dieselarbetslok	Diesel Work Train
Spårriktare	Track Alignment Machine
Ballast Plog	Ballast Cleaner
Spår Stabilisator	Track Stabiliser

Others:

Signalanläggning – Signal Lining

Elkräftanläggning – Electrical Lining

Terracing – Foundation Work and lying of under ballast or supra structure

Banöverbyggnad – Superstructure and Track laying

Drift och Underhåll – Operation and Maintenance