Straight and Curved Line Paths (SLiPs & CLiPs):

Developing the Targets and Predicting the Compliance

Discussion, Methodology and Example:
A Report to Regional Councils

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Scope

This discussion document outlines some of the key issues that should be considered by Regional Councils[1] when developing straight line paths (SLiPs) or curved line paths (CLiPs) when assessing compliance with the National Environmental Standards for Air Quality in 2005 and beyond. It is based on a preliminary assessment undertaken by Auckland Regional Council in March 2005, revised following the announcement of the amended regulations in July 2005, and is intended as a first step towards identifying the key factors influencing the development of SLiPs and CLiPs. This work is being undertaken as part of the Foundation for Research Science and Technology research programme on "Keeping Our Air Clean".

***Section 1** covers background on the National Environmental Standards and where the SLiPs and CLiPs fit in.*

***Section 2** contains a set of decision trees. These show the key questions that need to be to be addressed in order to develop a SLiP or CLiP and then how to assess compliance.*

***Section 3** has a worked example based on the preliminary assessment undertaken by the Auckland Regional Council.*

***Section 4** provides a set of comparisons in terms of equivalent particulate contributions from various sources as a first step towards identifying potential offsets.*

***The Appendix** outlines the key assumptions used to estimate background concentrations and the effect of various reduction strategies.*

[1] Throughout this document the reference to Regional Council includes those District and City Councils that have responsibility for managing the National Environmental Standards for Air.

1. Background

The National Environmental Standards for Air Quality (AQNES) were gazetted originally on 6 September 2004 but were recently amended on 28 July 2005 to clarify some definitions and to expand Regulation 17 to include provisions for curved line paths and offsets. The Ministry for the Environment has released a consolidated version[2] of the Regulations to assist Councils and other stakeholders in interpreting and implementing the AQNES.

The ambient air quality standards come into force on 1 September 2005. The two most immediate implementation issues currently facing Regional Councils are:

1. **Gazetting regional airsheds** or local air management areas (LAMAs)
2. **Developing straight line paths** (SLiPs) or curved line paths (CLiPs) for assessing compliance with the standards for 2005 and beyond

Regional Councils were asked to notify the Minister of the Environment with their region's proposed airsheds[3] by 1 July 2005, following which the Minister would gazette these . Fisher *et al*[4] have already provided some guidance on the key issues that need to be considered when setting these areas.

The latter issue is NOT a statutory requirement but is nonetheless essential for assessing or demonstrating compliance in areas where the AQNES is likely to be breached at any time from 1 September 2005 onwards, particularly with regards to Regulations 17, 17A, 17B, 17C, 18, and 19 of the AQNES. These regulations restrict the granting of consents for discharges of PM_{10} in polluted airsheds. Whilst SLiPs or CLiPs are not required to be gazetted it is anticipated that they are likely to be published by Regional Councils to indicate the effectiveness of various air quality management strategies to meet the AQNES. SLiPs and CLiPs will become a significant focal point for statutory documents that consider air quality. They will further be instrumental for industry seeking to obtain resource consents.

This document is a description and discussion of a methodology followed by the Auckland Regional Council as a first attempt to develop straight line paths. It covers some practical approaches that can be used, with suggestions given for values to use in the absence of detailed information on air pollution concentrations, emissions and projections. This is

[2] Ministry for the Environment, *Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations and Amendments 2005: Consolidated Version*, August 2005, covering SR2004/309, SR 2004/433, and SR 2005/214. Available at www.mfe.govt.nz/laws/standards/amendments.html

[3] In this discussion document *airsheds* and *LAMAs* are considered to be synonymous but, from this point on, the word "airshed" is used in preference to be consistent with the AQNES Regulations.

[4] Fisher *et al* 2005. *Defining New Zealand's Local Air Management Areas (LAMAs).* Information Resource for National Environmental Standards for Air Quality: Implementation, 5 July 2005. Available at

intended as a first cut to be reviewed as better information and analyses become available. Many of the assumptions are crude, but are based on practical experience and data that are currently available. Much remains to be done, but this exercise is useful for identifying and prioritising gaps and issues for future research efforts.

1.1. Which airsheds are SLiPs or CLiPs for?

According to the regulations, either a straight line path (SLiP) or a curved line path (CLiP) must be developed for any airshed in a region in which the concentration of PM_{10} **breaches the standard**.

For PM_{10}, the 24-hour mean concentration must not exceed 50 µg m^{-3} more than once in a 12 month period. Although not formally defined, the assessment period is likely to be a calendar year (1 January to 31 December). Two or more exceedences result in a **breach** of the standard. However, exceedences at two or more sites in the same airshed for the same time period are considered only one exceedence. Therefore a SLiP or a CLiP must be developed for any airshed in a region where the 24-hour PM_{10} concentration breaches the standard (i.e. concentrations exceed 50 µg m^{-3} at least two times per 12 month period) at any time.

It is important to note that a CLiP can only be used in preference to a SLiP **if the CLiP has been outlined in the regional plan <u>and</u> if there are rules** ensuring that resource consents are declined for applications that are likely to cause, at any time, the concentration of PM_{10} in the airshed to be above the CLiP (see Regulation 17B of the regulations for further details).

SLiPs or CLiPs are only referred to in the AQNES regulations (Regulations 17, 17A, 17B, and 17C) **when considering applications for resource consents to discharge PM_{10} in airsheds before 1 September 2013** if the concentration of PM_{10} already breaches the standard.

SLiPs or CLiPs are NOT required to be gazetted BUT it is recommended that they be made available for scrutiny to demonstrate and assess compliance with the National Environmental Standards. They will further be essential for the purpose of deciding whether resource consents to discharge PM_{10} can be granted, declined, or granted with offset conditions.

SLiPs or CLiPs are NOT required for other contaminants regulated by the AQNES (such as CO, NO_2, O_3, and SO_2) NOR are they required for airsheds that do not experience breaches of the PM_{10} 24-hour standard. However, it is recommended that Councils consider developing SLiPs for all contaminants in all regional airsheds anyway as they are a very useful air quality management tool for assessing effectiveness of various emissions reduction strategies. This is particularly important if pollutant levels are above 66% of the standard and are potentially increasing.

1.2. What are straight line paths (SLiPs) or curved line paths (CLiPs)?

Straight line paths (SLiPs) are defined in the AQNES amendments under Regulation 17 subclause (5) as *"… a straight line that –*

a. starts on the y-axis of a graph at a point representing, as at the relevant date, the extent to which the concentration of PM_{10} in the airshed breaches its ambient air quality standard; and

b. ends on the x-axis of the graph at a point representing, as at 1 September 2013, the ambient air quality standard for PM_{10} in the airshed."

The *relevant date* means –

a. *in the case of an airshed that is the region of a regional council, 1 September 2005:*

b. *in the case of an airshed that is part of the region of a regional council, the date of the notice in the Gazette that specifies the part to be a separate airshed*.

Curved line paths (CLiPs) are defined in the AQNES amendments under Regulation 17 subclause (5) as *"… a curved line that –*

a. starts on the y-axis of a graph at a point representing, as at 1 September 2005 or the date that the plan is publicly notified (whichever is the later), the concentration of PM_{10} in the airshed; and

b. ends on the x-axis of the graph at a point representing, as at 1 September 2013, the ambient air quality standard for PM_{10} in the airshed."

A CLiP can **only** be used when considering resource consents if the CLiP has been outlined in the regional plan **and** if there are rules ensuring that resource consents are declined for applications that are likely to cause, at any time, the concentration of PM_{10} in the airshed to be above the CLiP (see Regulation 17B of the AQNES for further details).

The SLiP or CLiP show the planned or target air quality performance set to meet the AQNES by 2013. Ideally, the SLiP should show either the representative number of exceedences or the representative maximum PM_{10} concentration at 1 September 2005 decreasing linearly to either one exceedence or a maximum PM_{10} concentration of 50 µg m^{-3} at 1 September 2013. In the case of a CLiP, the decrease over time will follow a curve rather than a straight line. Once a SLiP or CLiP (representing the **target air quality**) has been set, Councils need to monitor in that airshed and report the **actual air quality** against the SLiP or CLiP. The impact of start points is discussed in the example outlined in Section 3. The SLiP and an example of a CLiP are illustrated below in Figure 1.

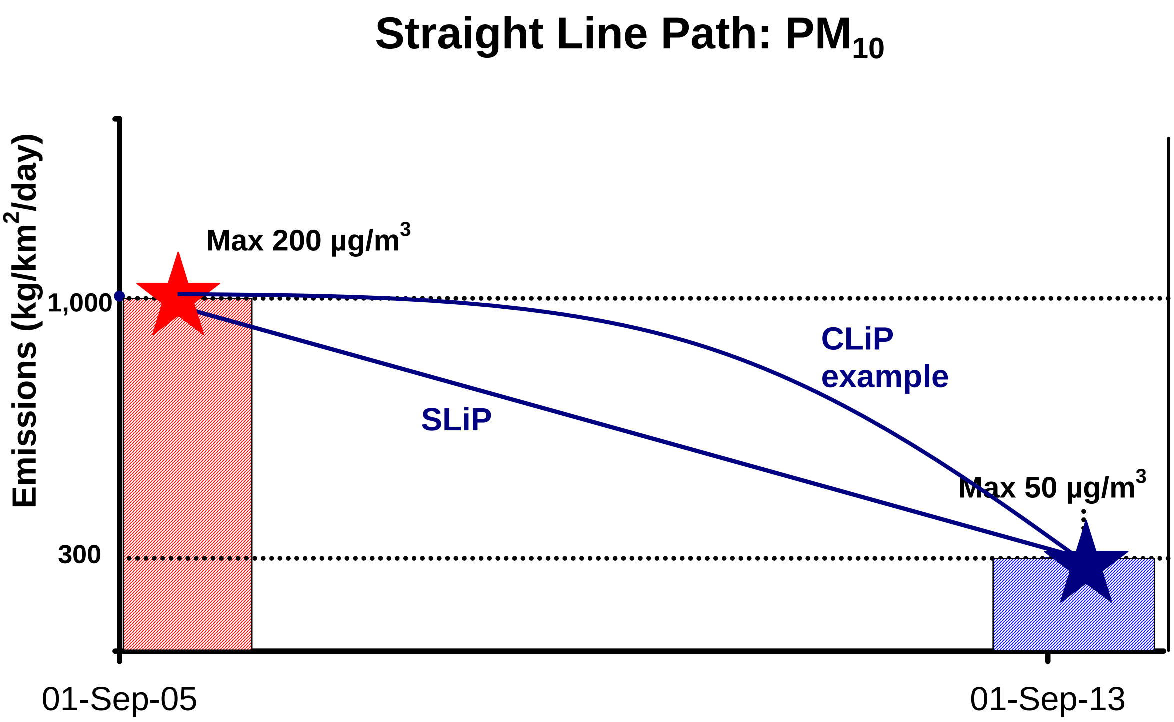

Figure 1. Straight line path, and curved line path example, illustrated.

The target air quality defined by the regulation and represented by the SLiP or CLiP shows what Councils have to do in theory to comply with the AQNES. The actual air quality shows how Councils are performing in reality versus the target. The area with most difficulty, that is critical for effective management of air quality to ensure the AQNES is met in any airshed in any region, is the **predicted air quality**. Air quality predictions need to be made based on a set of key assumptions (such as business-as-usual, plan changes, new consents, changes in fuel specifications etc.) to indicate whether Councils are likely to meet the AQNES or whether they need to develop additional reduction strategies. For the predicted air quality, the assessment and conducting of “what-if?” scenarios is most easily done based on emissions rather than concentrations (the reasons why emissions are preferable is demonstrated in the next section).

In summary, the three key parameters that need to be used to ensure compliance with the AQNES regulations are:

The **target air quality** represented by the SLiP or CLiP according to the AQNES regulation (related to either the number of exceedences or the corresponding maximum concentration).

The **actual air quality** represented by the monitoring data (related to either the number of exceedences or the corresponding maximum concentration).

The **predicted air quality** indicating the predicted air quality based on current and future management strategies (related to the emissions).

1.3. Why the focus on emissions rather than concentrations?

The key difficulty with the SLiP or CLiP approach mentioned in the Regulations is that although it is **relatively easy to measure actual concentrations** to show compliance with the standard, it is **extremely difficult to predict concentrations** in future. In a perfect world, Councils should use fully validated airshed model results for their region, based on complete and accurate emissions inventories, with detailed meteorology, and run these with reliable scenarios and predictions out for 10 or more years. In reality, very few Councils can afford to have such a sophisticated suite of air quality management tools and generally have to rely on much simpler and consequently cruder means to achieve the same ends.

Concentrations of contaminants in ambient air at a given location in an airshed depend on:

- where the sources are located (both horizontally and vertically, effect of terrain);
- how much the sources emit (emissions);
- when the sources are active (both time of day and time of year);
- what the weather is doing (calm, windy, and whether there are temperature inversions).

Other factors are also important and need to be considered (such as demographic changes, technology evolution, transport patterns, industry consent changes, growth).

Of these, information about the size and location of source emissions is generally the easiest to estimate using regional or national air emissions inventories. As a consequence, **emissions can be used as a proxy for concentrations with the following proviso**.

Ambient concentrations depend on a number of things including emissions BUT the relationship between concentrations and emissions may not be precisely linear. This means that a 30% reduction in concentration may only be achievable with a greater than 30% reduction in emissions. Therefore if emissions are to be used as a proxy then some safety margin needs to be built in to the future predictions to ensure compliance with the standard in future years. The example covered later in this discussion document assumes a 20% safety margin i.e. a 10% reduction in concentration requires a 12% reduction in emissions. On current understanding, 20% seems a reasonable safety margin based on typical annual variations in meteorology however Councils may prefer to go with 0% if they consider that their local meteorology is more predictable, or they have greater evidence of the nature of the emissions-concentration relationship in particular airsheds.

Effective regional management of air quality to meet the AQNES requires reliable predictions of future air quality. Such predictions are themselves dependent on emissions inventories and airshed models. These processes are highly variable in their output depending on the assumptions made and how they are used. Unless the predictions are well justified through analysis, monitoring, modelling, or consensus, they can be undermined. One of the aims of this document is to recommend a consistent approach in order to make the necessary predicitons as robust as possible with the current state of knowledge.

1.4. What tools are available to help?

The six basic tools are:

1. **Emissions Inventories:** How much material is being emitted, where and when.
2. **Modelling:** How the material is transported around the region and where it ends up.
3. **Monitoring:** Measurements to confirm and validate what is going on.
4. **Geophysical Information (including meteorology):** Locations, hills, valleys, weather.
5. **Growth Projections:** Changes in population, industrial development, vehicle use.
6. **Emissions Factors:** Rates of emissions and how these might change in future.

These are the tools that can be used to quantify the process for setting SliPs and CliPs and the mitigation measures that might be needed. A further range of tools is available to help achieve the outcomes – the standards themselves, other regulatory instruments, communication and education, and related advanced strategies and policies. These are discussed in detail in the Users Guide to the regulations[5].

Some Councils have good information on these factors (such as technology changes, policy implementation, and reduction methodologies), whereas others have access to very little quantitative information. However, some reasonable estimation methods are available, using data that can be relatively easily obtained (e.g. from Statistics NZ).

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[5] The Users Guide to Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004. Ministry for the Environment, 2004. Available at www.mfe.govt.nz

2. Decision Trees for the SLiPs and Prediction Process

The two key questions directly arising from the requirements in the AQNES regulations are:

- What is the representative peak 24-hour PM_{10} concentration now (in 2005) – **the "start point"**?
- What **reductions** are required from the various contributing sources to achieve the standard by 2013?

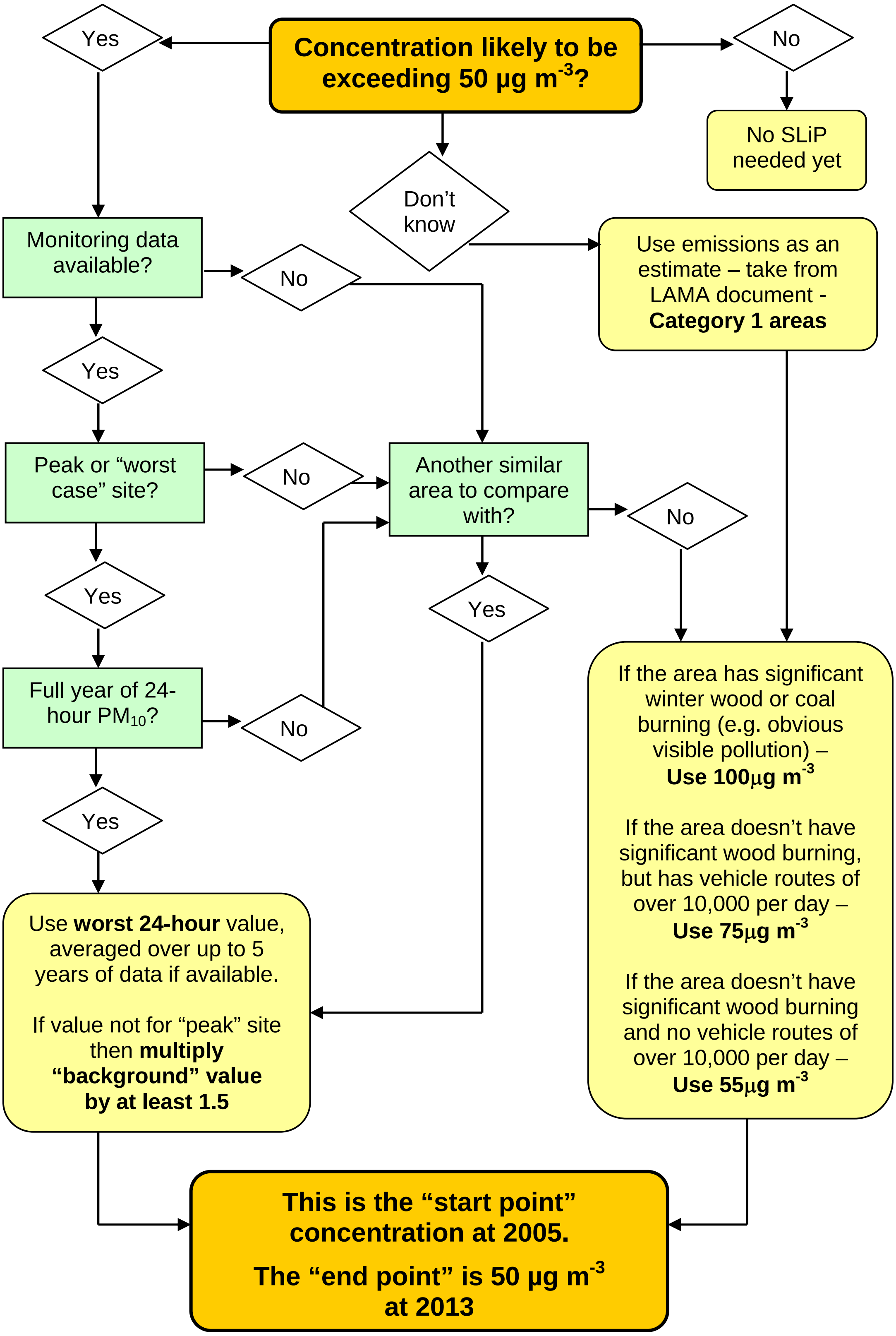
This second question must address all three main source categories – domestic, transport and industrial. The proportion of effects due to each source can vary significantly between regions, and will need specific mitigation policies that may be different in even adjacent airsheds. The substantial year-to-year variability in emissions and weather factors leading to exceedences must also be taken into account. This is remarkably difficult to do explicitly, but must be considered in the process.

A further complication lies in the treatment of 'natural' sources of PM_{10} - ie those that cannot be influenced by Council policy or regulations (such as sea salt, wind blown dust, pollen, rural fires, volcanic emissions, etc). However in order to assess percentage reductions required, some assessment needs to be made of the conrtribution of these sources to any exccedence – current or potential. This is not a simple task, as (a) few assessments have been made, (b) natural sources are highly varibale and mostly unquantified, and (c) elevated concentrations due to natural sources can occur at times when contributions from other sources are low (eg in windy periods).

The approach followed here is to use <u>decision trees</u> to aid the process. These are formulated to provide some consistency of approach, and to give some structure to the process of determining straight line path parameters.

2.1. Decision Tree 1 – Start and End Points

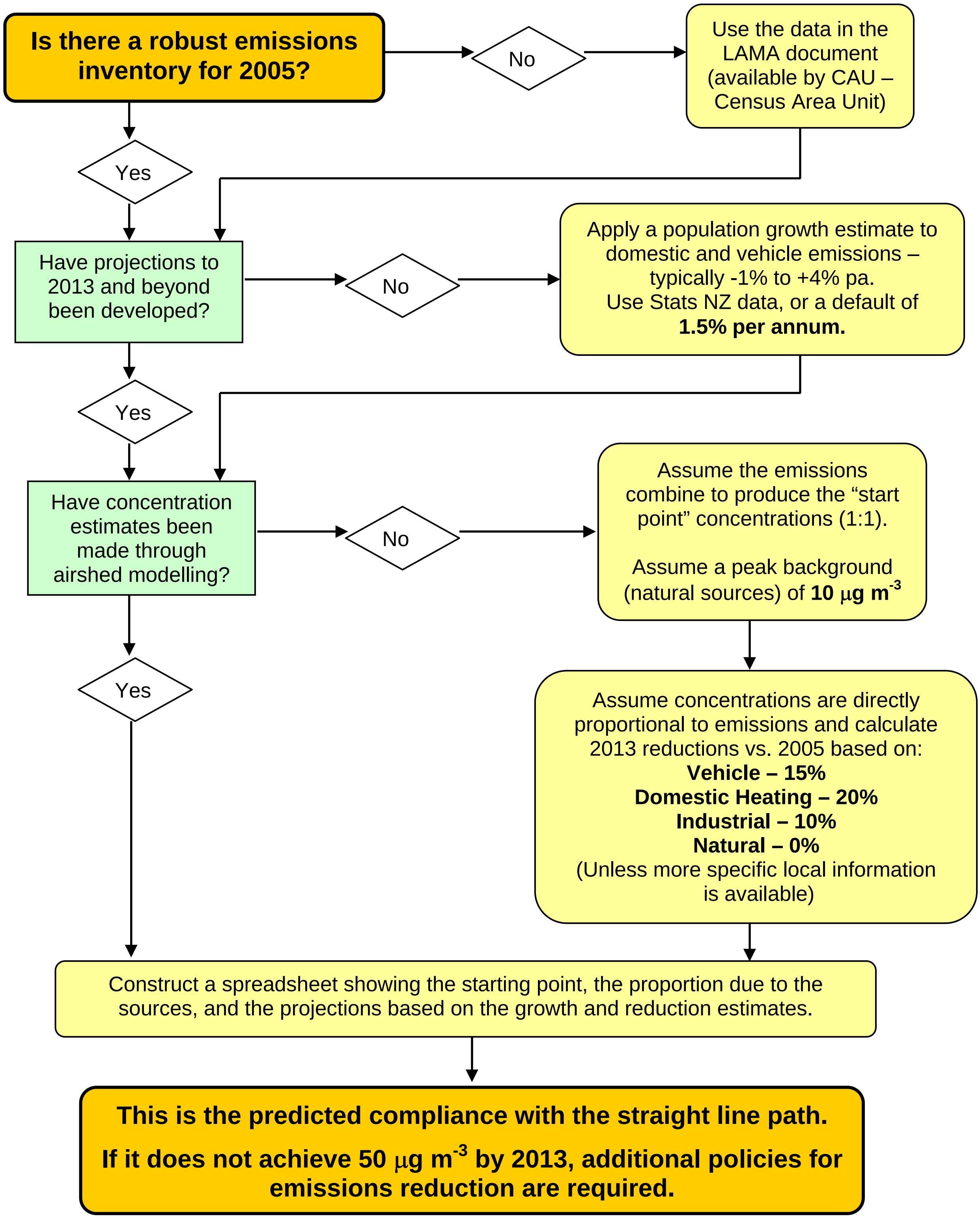
The following decision tree is based upon key assumptions outlined in the Appendix. For each airshed that has been gazetted:



This start point value should and can be revised if better information becomes available during the process or at any time in the future.

2.2. Decision Tree 2 – Predictions of Likely Compliance

The rationale for the proposed numerical values and percentage reductions is given in the Appendix. For each airshed that has been gazetted, with an assigned start point value:



A worked example for the Auckland region is given in the next section.

3. Case Study Example for the Auckland Region

3.1. Background

The Auckland region experiences a high contribution of air pollution and associated health impacts from motor vehicles (between 50-80% depending on the pollutant). This means that the calculation of emissions from vehicles and the reduction in those emissions is critical to the possibility of meeting the AQNES.

A significant issue for the Auckland region is whether the transport emissions reductions necessary to meet the AQNES will be able to be realised as transport is the largest single contributor of emissions.

However, whilst the motor vehicle issue is related to the large traffic volumes (750,000 vehicles and 11 billion vehicle kilometres travelled per year in 2005), the following comparison shows that other sources can be significant.

For PM_{10} emissions:

1 typical open fire @ 15 g/kg for 1 night =

1 typical NES wood burner @ 1.5 g/kg for 10 days =

1 typical Euro II (post-1996) petrol car for 1 year (15,000 km)

Industrial discharges are also significant but only equate to 5-10% of the PM_{10} mass emission in Auckland. Furthermore these discharges are usually through high stacks and therefore are less significant at ground level.

For PM_{10} emissions:

400 MW (new combined cycle gas fired) power station for 1 year =

26 typical open fires @ 15 g/kg for 3 months =

5 typical Euro 0 (pre-1992) diesel trucks for 1 year (50,000 km)

The 100,000 diesel trucks in the Auckland region would easily swamp PM_{10} emissions from a large power station by a factor of 20,000. A similar picture emerges with the estimated

130,000 domestic heating appliances across Auckland. Each of these emit somewhere between 1.5 g/kg and 20 g/kg of wood burnt and collectively they would overwhelm a power station PM_{10} emissions by a factor of 5,000.

3.2. Start and End Points

This section follows the decision tree outlined in section 2.1 using data for the Auckland region.

Step 1: Which airsheds need to be considered for developing SLiPs or CLiPs?

The Auckland region has only one (albeit large) Category 1 airshed. This airshed has been gazetted and covers essentially the entire urbanised area of the region bounded by the Metropolitan Urban Limit (MUL), which is aligned to the Auckland Regional Plan: Air, Land and Water. All of the answers to the following questions relate to this airshed. If the Auckland region had more than one Category 1 airshed, these questions would have to be asked for each and every airshed.

Step 2: Is the PM_{10} 24-hour concentration likely to be exceeding 50 μg m^{-3}?

Yes.

Step 3: Are PM_{10} monitoring data available?

Yes.

Step 4: Do the PM_{10} data come from a likely "peak or worst case" monitoring site/s?

Yes.

Step 5: Do we have a full year of 24-hour PM_{10} data at the site/s?

Yes.

Step 6: Determine the likely "worst 24-hour PM_{10}" concentration

Table 1 summarises the exceedences recorded for PM_{10} 24-hour concentrations in the past 5 years (from January 2000 to December 2004). The big question is which number to select as the "worst" value? Examining the data:

The **5 year <u>average maximum</u> is 76.2 μg m^{-3}**

calculated from the 5 yr average of the highest exceedence recorded for each year

i.e. (94.6 + 72.3 + 94.5 + 62.0 + 57.7) / 5 = 76.2

The **5 year <u>average mean</u> is 63.6 μg m^{-3}**

calculated from the 5 yr average of the average exceedence recorded for each year

i.e. (71.4 + 60.2 + 75.0 + 62.0 + 57.7) / 5 = 76.2

The **5 year <u>overall maximum</u> is 94.6 μg m^{-3}**

calculated from the highest exceedence value recorded for the past 5 yrs

Table 1. Summary of PM_{10} exceedences in the Auckland region* for 2000-2005

(*for the Category 1 Airshed bounded by the MUL)

Year & (No of Exceedences)	Date	Where	Concentration ($\mu g\ m^{-3}$)	Year Max	Year Mean
2000 (5)	26-Apr-00	Khyber Pass	51.3	**94.6**	71.4
	26-Apr-00	Queen St	84.1		
	30-Aug-00	Penrose (ACI)	57.4		
	16-Dec-00	Khyber Pass	94.6		
	28-Dec-00	Queen St	69.8		
2001 (7)	8-Feb-01	Khyber Pass	68.7	72.3	60.2
	4-Mar-01	Mt Eden	51.1		
	10-Mar-01	Penrose (ACI)	55.3		
	9-Apr-01	Queen St	53.8		
	5-Jun-01	Penrose (ACI)	72.3		
	5-Jun-01	Takapuna	62.3		
	11-Jul-01	Queen St	57.7		
2002 (3)	8-Mar-02	Khyber Pass	64.9	94.5	75.0
	14-Mar-02	Khyber Pass	94.5		
	25-Apr-02	Khyber Pass	65.7		
2003 (3)	13-Jun-03	Penrose (ACI)	54.0	62.0	56.4
	22-Jul-03	Penrose (ACI)	53.3		
	22-Jul-03	Penrose (Gavin St)	62.0		
2004 (2)	27-Mar-04	Queen St	52.6	57.7	55.2
	14-Jul-04	Takapuna	57.7		
2000-2004 Average				**76.2**	**63.6**

Auckland Regional Council are fortunate to have five years worth of monitoring data and so are able to take into account some effect of inter-annual variations in meteorology by averaging the values over five years. It is highly unlikely that the emissions have changed significantly between 2002 (which recorded 3 exceedences and a maximum 24-hour concentration of 94.5 $\mu g\ m^{-3}$) and 2003 (which also recorded 3 exceedences but a much lower maximum 24-hour concentration of 62.0 $\mu g\ m^{-3}$). Therefore, the difference is most likely to be related to meteorology. As the maximum concentrations vary by a factor of 50%, thus it is “safer” (in order to be more confident of meeting the AQNES) to opt for the 5 year *average maximum* of 76.2 $\mu g\ m^{-3}$ to ensure that some account is taken of trends in meteorology. Alternatively, choosing the highest maximum recorded for the past 5 years (94.6 $\mu g\ m^{-3}$) would not necessarily be without justification but would have a very significant impact on the SLiP.

Therefore for the development of the SLiP* for the Category 1 (MUL) airshed:

The “start pt” is 76.2 $\mu g\ m^{-3}$ at 2005 and the “end pt” is 50.0 $\mu g\ m^{-3}$ at 2013 onwards.

** ARC is required to choose a SLiP because the plan does not have provision nor rules for a CLiP*

In section 3.4, the impact of opting for alternative "start point" values on the emissions reductions required to meet the AQNES is assessed.

3.3. Predictions of Likely Compliance with the SLiP

This section follows the decision tree outlined in section 2.2 using data for the Auckland region, using the same airshed from the previous section with the calculated start point concentration for the SLiP.

Step 1: Is there a robust emissions inventory for 2005?

An updated air emissions inventory for 2004 has just been completed with estimates for 2011 and 2021, from which it is possible to "interpolate" 2005 data (see Table 2). It is unlikely that emissions will vary significantly between 2004 and 2005 so the estimates are considered to be sufficiently "robust". In addition, the "start point" for the straight line path (SLiP) in the previous section is based on data up to the end of 2004 only.

Table 2. Estimates of PM_{10} annual emissions for Auckland* in 2005 (tonnes/yr)

(*estimated for the Category 1 Airshed bounded by the MUL)

Year	2004	2005 (interpolated)	2011
Industry	810	810	813
Domestic Heating	2,330	2,287	2,026
Transport^{+}	2,776	2,689	2,169
Biogenic^{++}	nil	nil	nil
Total	**5,916**	**5,786**	**5,008**

$^{+}$ Transport does not include any estimates for PM_{10} arising from road dust (this is incorporated into the background concentration calculations)

$^{++}$ Biogenic does not include any estimates for PM_{10} arising from sources such as windblown dust and sea salt (this is incorporated into the background concentration calculations)

Step 2: Have projections to 2013 and beyond been developed?

An updated air emissions inventory for 2004 estimates this for 2011 and 2021, from which it is possible to "interpolate" 2013 data (see Table 3).

Table 3. Estimates of PM_{10} annual emissions for Auckland* in 2013 (tonnes/yr)

(*estimated for the Category 1 Airshed bounded by the MUL)

Year	2011	2013 (interpolated)	2021
Industry	813	814	818
Domestic Heating	2,026	1,976	1,775
Transport+	2,169	2,103	1,837
Biogenic++	nil	nil	nil
Total	**5,008**	**4,892**	**4,430**

+ Transport does not include any estimates for PM_{10} arising from road dust (this is incorporated into the background concentration calculations)

++ Biogenic does not include any estimates for PM_{10} arising from sources such as windblown dust and sea salt (this is incorporated into the background concentration calculations)

Step 3: Have concentration estimates been made through airshed modelling?

No, not yet... so a relationship between emissions and concentrations needs to be developed.

Step 4: Make assumptions for relationship between emissions and concentrations

Assume emissions combine to produce the start point concentrations (1:1) in the absence of “better” information.

Assume peak background concentration of 10 µg m^{-3} to cover windblown dust, sea salt and road dust.

Assume the rest of the emissions are as per the emissions inventory.

Assume that the background concentration remains constant for future years but that the rest of the emissions reduce as per the projections for “business as usual” (BAU) for 2013 in the emissions inventory as it currently stands.

Step 5: Construct a spreadsheet showing the start point, the proportion due to sources and the projections based on BAU growth and reduction estimates.

Table 4 and Figure 2 show the likely compliance (in terms of the predicted maximum 24-hour PM_{10} concentration calculated from the emissions trends) versus the target set by the SLiP for 2005 and beyond. These show that current "business as usual" (BAU) policy will be insufficient to guarantee compliance with the SLiP and the AQNES by 2013.

Table 4. Predicted concentration of Auckland* vs the AQNES SLiP assuming BAU policy

(*estimated for the Category 1 Airshed bounded by the MUL)

Year	2005	2013	2021
Max Allowable 24 hr Concentration (μg/m^3)	**76.2**	**50.0**	**50.0**
Predicted Concentration from Emissions (μg/m^3)	**76.2**	**66.0**	**60.7**
Background (assume constant)	10.0	10.0	10.0
Industry	9.3	9.3	9.4
Domestic	26.2	22.6	20.3
Transport	30.8	24.1	21.0
Biogenic	nil	nil	nil
Total Annual PM_{10} Emissions (tonnes/yr)	**5,786**	**4,892**	**4,430**
Industry	810	814	818
Domestic	2,287	1,976	1,775
Transport	2,689	2,103	1,837
Biogenic	nil	nil	nil

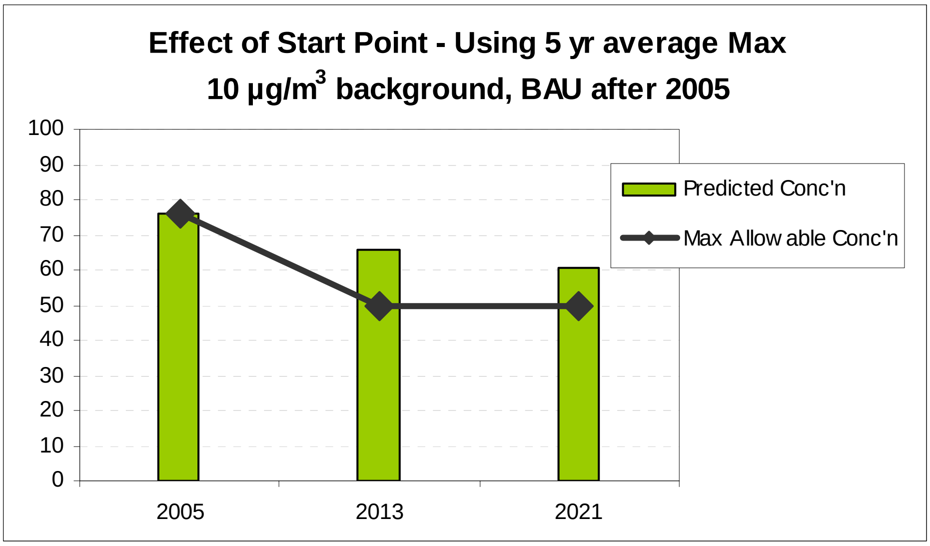


Figure 1. Predicted ability of Auckland* to meet the AQNES SLiP assuming BAU emissions reduction policy

Emissions are currently predicted to reduce from 2005 levels by 15% in 2013 but need to reduce overall by at least 41% in 2013 and linearly every year in between to achieve minimum compliance (without any safety margin). **Given that BAU policy will not meet the AQNES by 2013 nor achieve the SLiP for the years in between, what sort of reductions are needed to guarantee compliance?**

Looking at the inventory data and assumptions factored into the estimates, major additional policies or initiatives will be needed in order to deliver the following kinds of reductions needed to guarantee compliance:

- 30% reduction in industrial emissions by 2013 due to on-going process and control improvements
- 60% reduction in domestic emissions by 2013 due to incentives for home heating appliance replacements
- 60% reduction in vehicle emissions by 2013 through some form of in-service emissions screening (20%) plus heavy/light commercial retrofit programme (40%)

Table 5 and Figure 3 compare the likely compliance (in terms of the predicted maximum 24-hour PM_{10} concentration calculated from the emissions trends) versus the SLiP target assuming the more aggressive, major changes in emissions reduction policy, outlined above.

Table 5. Predicted concentration of Auckland* vs the AQNES SLiP assuming major changes in policy

(*estimated for the Category 1 Airshed bounded by the MUL)

Year	2005	2013	2021
Max Allowable 24 hr Concentration (μg/m³)	**76.2**	**50.0**	**50.0**
Predicted Concentration from Emissions (μg/m³)	**76.2**	**39.3**	**39.3**
Background (assume constant)	10.0	10.0	10.0
Industry	9.3	6.5	6.5
Domestic	26.2	10.5	10.5
Transport	30.8	12.3	12.3
Biogenic	nil	nil	nil
Total Annual PM_{10} Emissions (tonnes/yr)	**5,786**	**2,558**	**4,430**
Industry	810	567	567
Domestic	2,287	915	915
Transport	2,689	1,076	1,076
Biogenic	nil	nil	nil

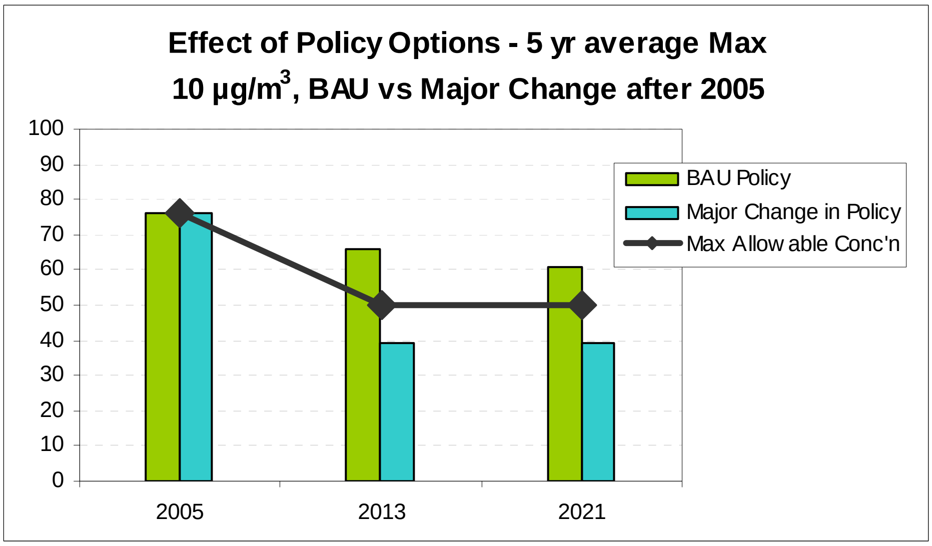


Figure 3. Comparison of the ability of Auckland* to meet the AQNES SLiP with major policy changes vs BAU emissions reduction policy

The "major change" emissions scenario shows a predicted maximum 24-hour concentration of 39 µg m^{-3} which is well below the 50 µg m^{-3} maximum concentration allowed by the AQNES (for one exceedence only). This is deliberate to provide a valuable safety margin between the predicted maximum and the legal maximum. This further provides some contingency for errors in the assumptions, such as

- The **effect of meteorology on the relevant start point concentration** may have been under-estimated, even by using 5 year averages. ARC are in the fortunate position to have 5 years worth of monitoring data but climatic trends can occur over longer periods. Further analysis of the climate record that the past 5 years may show that there were in fact good years for air pollution dispersion, which would make achieving the target even more difficult! (See the next section for a discussion on the effect of "start point" concentration).
- The **background concentration** may be found to be higher than the 10 µg m^{-3} currently estimated. This number is assumed to cover the contribution of wind blown dust, sea salt and road dust – however the latter alone may contribute 10 µg m^{-3} just by itself. ARC are currently undertaking source apportionment to better firm up this estimate. (See section 3.4.2 for a discussion on the effect of background concentration).
- The **emissions estimates are based on annual data**, not on data for "worst case" summer or winter days. Even where inventory data are broken down by season, the numbers have still been estimated for an "average" winter's day rather than a "worst case" winter's day. (See section 3.4.3 for a discussion on the effect of seasonality).

- There is no account of the effect of **secondary particulate** formation on actual PM_{10} concentrations, which could be significant for Auckland, especially considering the NOx emissions in the region.

Of these, the greatest uncertainty lies in the relationship between the peak 24-hour exceedence for PM_{10} and the annual average mass emission rates derived from emission inventories. This relationship will be difficult to determine considering the random spread of the days when the AQNES is exceeded currently. This relationship may be quite different in other parts of New Zealand and must be well understood before a defensible level of certainty can be reached. This level of certainty is required for consent processes, particularly after 2013.

It should be noted that this worked example is just the preliminary assessment for the Auckland region. A number of related projects are already underway to provide better confidence in the numbers by firming up the estimates and establishing realistic confidence intervals. Emissions inventory estimates and monitoring data will need to be constantly reviewed.

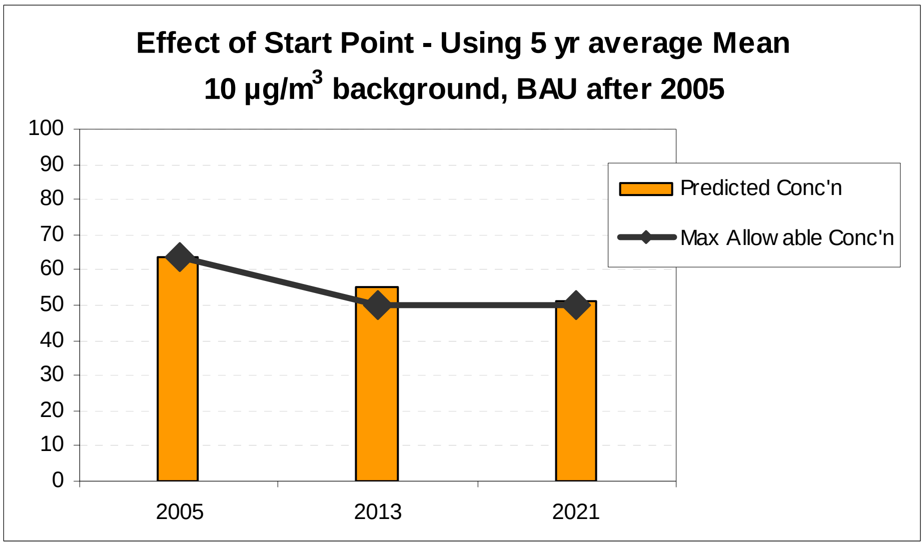
Unfortunately calculating the emissions reductions needed is the easy part; achieving the reductions is where the challenge really begins with behaviour change and political courage ultimately influencing our ability to improve air quality rapidly and successfully enough to meet the AQNES.

3.4. Sensitivity Analysis

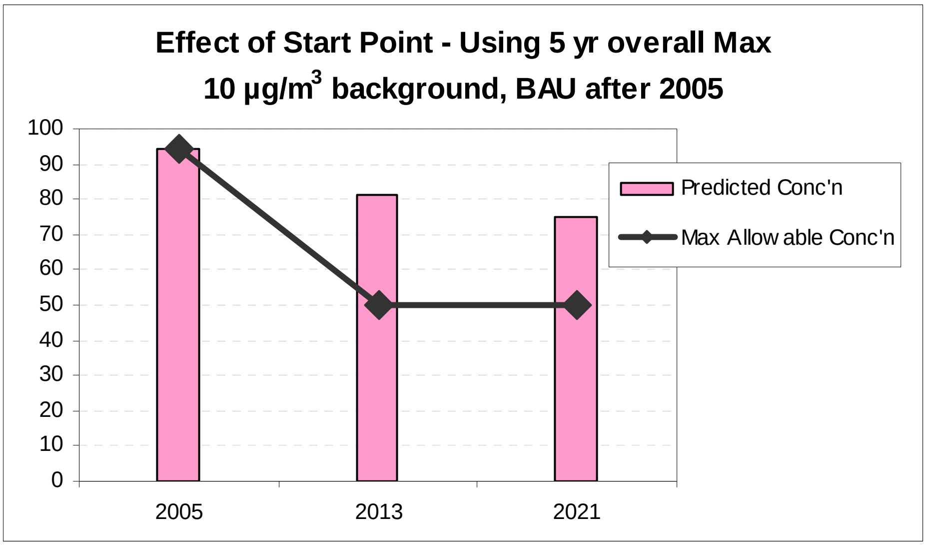
This section highlights the effect of key parameters on the predicted likely compliance, using the Auckland data from the previous section.

3.4.1. Start Point

Figure 4 shows the impact of the choice of start point on the ability to meet the SLiP. These were developed using (a) the 5 year *average mean* (63.6 $\mu g\ m^{-3}$) and (b) the 5 year *overall maximum* (94.6 $\mu g\ m^{-3}$) from Table 1. For each of these, the estimated reduction in emissions to achieve minimum compliance with the SLiP is also shown.



(a) Using **63.6 µg m^{-3} as a start point** requires a 21% emissions reduction for minimum compliance and is nearly achieved with BAU policy



(b) Using **94.6 µg m^{-3} as a start point** requires a 47% emissions reduction for minimum compliance but will not be achieved without major policy changes

Figure 4. Comparison of the ability of Auckland* to meet the AQNES SLiP depending on the start point concentration selected

Under the first scenario (using the 5 year *average mean*) compliance can almost be achieved without new reductions policy but for the other scenario (using the 5 year *overall maximum*), compliance will not be achieved without significant new measures.

Setting the start point concentration high requires more aggressive emissions reductions but is more likely to guarantee actual compliance (assuming the reductions are achieved). Setting the start point concentration low means that less intervention over BAU policy is required but any error in the assumptions will make an actual breach of the target SLiP more likely, thereby jeopardising the ability to issue consents for industry.

3.4.2. Background Concentration

Figure 5 shows the impact of the assumed background concentration on the ability to meet the SLiP. The first case assumes a 5 µg m^{-3} contribution from background sources (including windblown dust, sea salt, and road dust) and teh second case a background of 20 µg m^{-3}. These plots use the base scenario of a start point based on the average of 5 yearly maximum exceedences (76.2 µg m^{-3}) and BAU policy from 2005.

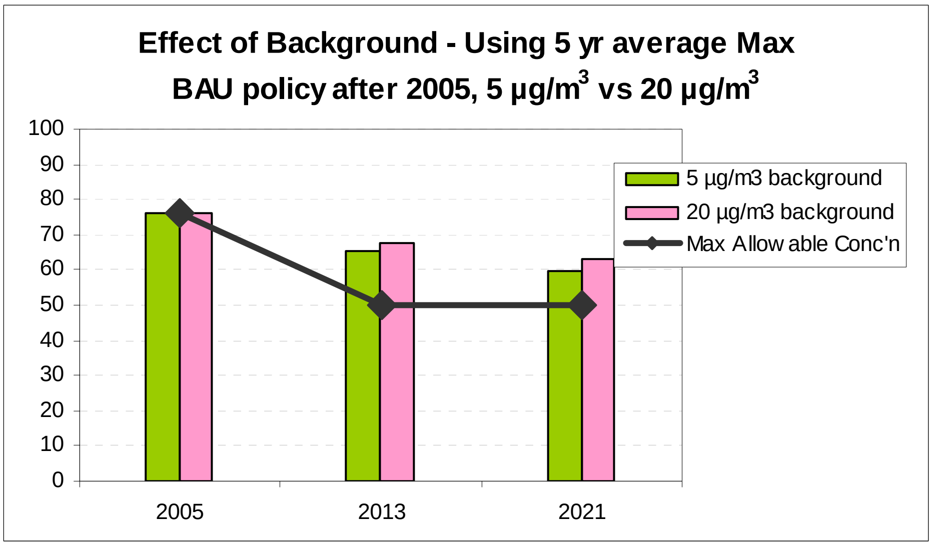


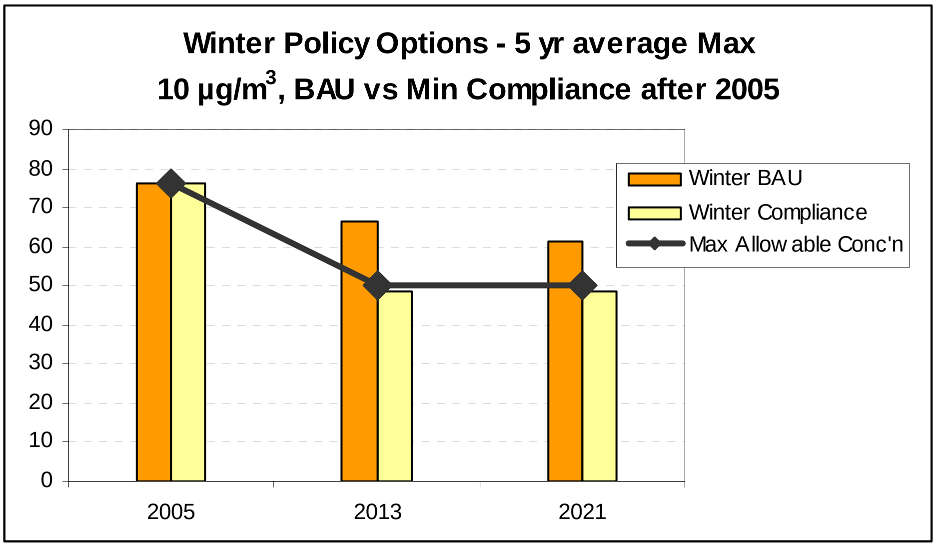
Figure 5. Comparison of the ability of Auckland* to meet the AQNES SLiP depending on the background concentration selected

The higher the expected background concentration, the greater the reductions needed from the other sources in order to achieve compliance.

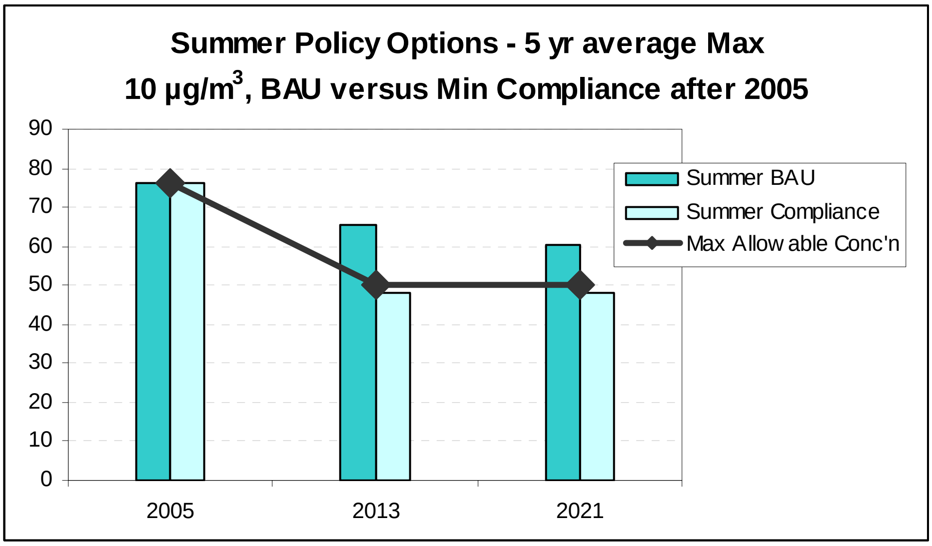
3.4.3. Seasonality

Figure 6 shows the predicted ability to meet the SLiP assuming the start point concentration applies equally to a typical winter's day (at 29.4 t/day PM_{10}) or a typical summer's day (at 10.5 t/day PM_{10}) rather than an annual average day (at 16.2 t/day). In winter, the bulk of the emissions (~65%) are estimated to come from the domestic sector (19.0 t/day) with 7.8t/day coming from the transport sector (~27%). In summer, the contribution from the domestic sector reduces to nearly zero with the bulk of the emissions (~74%) coming from the transport sector.

In neither the winter's day example nor the summer's day example does BAU policy achieve compliance with the AQNES. Minimum compliance can only be achieved in winter with 44% reductions in both domestic and transport emissions combined with a 22% reduction in industrial emissions. In summer, however, transport emissions must be reduced by at least 50% to achieve minimum compliance. This is because of the disparity between typical winter's day PM_{10} loads (29.4 t/day) and typical summer's day PM_{10} loads (10.5 t/day) as well as the different emissions proportions for each season.



(a) Minimum compliance in winter requires a 42% daily emissions reduction with 22% from industry, 44% from domestic, and 44% from transport



(b) Minimum compliance in summer requires a 43% daily emissions reduction with 22% from industry, 0% from domestic, and 50% from transport

Figure 6. Comparison of the ability of Auckland* to meet the AQNES SLiP depending on the season

Consideration should be given to building in a safety margin (say 20% on the predictions) to counter uncertainties in the data.

4. Example PM_{10} Emissions Comparisons

The following estimates compare various typical activities covering the three principal sources – domestic fires, motor vehicles, and power stations (industry) - that result in similar PM_{10} emissions to indicate the type and magnitude of offsets possible and highlight the relative contributions of various sources. **The emissions factors and the activity rate data (e.g. fuel consumption, mileage travelled etc.) are typical values intended to provide guidance in the absence of more detailed information.** The power station emissions data, in particular, are highly dependent on the level of control technology employed and can perform significantly better or worse than the indicated data. If more robust data are available, these can be used to confirm the comparisons.

Domestic Fires

Appliance Type	Emission Factor	Typical Winter's Night Fuel Use	PM_{10} Emissions
typical open fire	15 g/kg	10 kg	150 g/night
typical NES w/burner	1.5 g/kg	10 kg	15 g/night

Motor Vehicles

Vehicle Type	Emission Factor	Typical Annual Mileage	PM_{10} Emissions
typical Euro II (post-1996) petrol car	0.01 g/km	15,000 km	150 g/year
typical Euro 0 (pre-1992) diesel truck	1.40 g/km	50,000 km	70,000 g/year

Power Stations

Size and Fuel Type	Emission Rate	PM_{10} Annual Emissions	PM_{10} Daily Emissions
typical 400 MW gas	0.533 g/s	16,800 kg/yr	46,027 g/day
best 400 MW gas	0.011 g/s	350 kg/yr	959 g/day
typical 1 MW coal	0.200 g/s	6,300 kg/yr	17,260 g/day
best 1 MW coal	0.020 g/s	630 kg/yr	1,726 g/day

Source Comparisons

Comparison	PM_{10}	Equivalent Sources
1 typical open fire for 1 night =	150 g	• 1 typical Euro II petrol car for 1 year • 1 typical NES w/burner for 10 nights • 1 typical 1 MW coal p/station for 2 hrs • 1 typical 400 MW gas p/station for 5 mins
1 typical 1 MW coal p/station per day =	17,260 g	• 115 typical open fires for 1 night • 1150 typical NES w/burners for 1 night • 115 typical Euro II petrol cars for 1 year
1 *best* 400 MW gas p/station per year =	350 kg	• 2,333 typical open fires for 1 night or 26 typical open fires for 3 mths • 23,333 typical NES w/burners for 1 night or 259 typical NES w/burners for 3 mths • 5 typical Euro 0 diesel trucks for 1 year

Appendix – Key Assumptions

The determination of the straight line paths is critically dependent on the emissions reduction estimates, as well as some other assumptions – including the nature of background concentrations, the relationship between emissions and monitored concentrations, and inter-annual weather factors. The figures suggested here are best estimates based on current information, all subject to revisions. The sector reductions proposed are based on current understanding and relate to PM_{10} emissions only.

A.1 Peak Site Factor of 1.5

For determining starting points based on monitoring that may not be located at a peak site, it is suggested that an enhancement factor of 1.5 be applied. This is based on nominal relationships within the Auckland airshed, where peak sites tend to show annual PM_{10} concentrations that are up to 1.5 times those from non-peak sites.

Other regions are advised to use this factor with caution, and where possible it should be based on monitoring data, even if only a modest amount is available.

A.2 Starting Concentrations of 100, 75 and 55 μg m^{-3}

Where SLiPs or CLiPs need to be developed in areas where there is no useable of monitoring data (there are several airsheds that may be in this situation) some estimation needs to be made in order to progress the planning. This situation is expected to improve reasonably quickly, especially with the recent Ministry for the Environment grant to Councils that has enabled the purchase of 16 new PM_{10} monitors. However for first stage plans, these default concentrations are recommended on the following basis:-

- If the area has significant winter wood or coal burning (e.g. obvious visible pollution) – this is a situation akin to Christchurch and many other towns (some quite small) that experience winter-time problems due to home heating emissions. In areas that have been well monitored (Christchurch, Nelson, Timaru, etc) daily concentrations over 100 μg m^{-3} are experienced. It is likely that most of the urban areas experiencing these high concentrations have already been identified by the relevant Council and will be explicitly accounted for in the setting of the starting point. However there are likely to be other areas that have not yet been explicitly assessed by monitoring, that could have peak concentrations well above the standard. An appropriate conservative value is needed for the starting point, nominal recommended as twice the standard. **Use 100 μg m^{-3}**

- If the area doesn't have significant wood burning, but has vehicle routes of over 10,000 per day – this is a situation where local traffic hot spots could lead to exceedences. Concentrations above the standards have been observed along side busy roads in various cities (Auckland, Christchurch, Nelson, Napier, Tauranga, etc). A nominal traffic volume factor has been assessed at 10,000 per day[6]. A suitable nominal value for the starting point is 50% over the standard. **Use 75 μg m^{-3}**

- If the area doesn't have significant wood burning and no vehicle routes of over 10,000 per day – this is the situation where perhaps there are no obvious large area sources (domestic or vehicle), but there are reasons to include this airshed in the management regime – say due to particular geographic factors, local industry, or specific community concerns. A nominal starting value of 10% over the standard is recommended. **Use 55 μg m^{-3}**

A.3 Population Growth

Population growth estimate for domestic and vehicle emissions – typically -1% to +4% pa. Use Statistics NZ data, or a default of **1.5% per annum.,** which is the average net national growth rate over the last 3 years (1.4% in 2002, 1.7% in 2003, 1.3% in 2004). Again, more specific regional data is preferable, since population growth is variable, and has even been negative in some areas.

A.4 Background PM_{10} Concentration of 10 μg m^{-3}

How to handle background and natural sources is problematic. These are highly variable, and there is little information. Some estimate has to be made, since the proportion of background can greatly affect the percentage reduction calculation. Typical background sources – largely "natural" rather than domestic, transport or industrial – include sea spray, wind blown dust, pollen, bushfires, agricultural activities (plowing, burning, decay), biogenic (emissions directly from plants), re-entrained road dust and probably numerous other minor sources not otherwise accounted for. Another undefined source is secondary particulate from rural activities (fertiliser and animal waste) which has been found to have significant impact on urban areas overseas. These are all lumped together as they all fall into a general category of emissions that are difficult or impossible to control by regulation or Council policy.

Few studies have been done on background concentrations in New Zealand. Measurements made in areas where there are no obvious other sources typically show values less than 10 μg m^{-3}, although higher values can occur in areas such as Taranaki and north Canterbury

[6] This factor is being developed at present as part of the work for "The Good Practice Guide for Assessing Vehicle Emissions", being undertaken by the ARC, MfE, and Transfund. It is only nominal, since it does depend on fleet profiles and geographical factors.

due to high sea spray rates. Pollen episodes in regions like the Wairarapa could lead to high concentrations over periods of a few days. Obviously areas experiencing burn-off or fires can have very high concentrations. One study done in Christchurch[7] suggested an annual average background of 3.8 $\mu g\ m^{-3}$, but this is not indicative of the 24-hour peak that is of interest here. There is another complex issue in that peak background levels may not occur at the same time as peak anthropogenic source contributions.

However the focus of the regulations is on worst cases. On this basis, the use of 10 $\mu g\ m^{-3}$ is appropriate, applying the precautionary principle. It could be slightly higher or lower, depending on the region. It could easily be a lot higher in specific one-off circumstances, such as bush fires – but this is accounted for in the one allowable exceedence in the regulations – so this aspect is not considered further.

The actual peak background anywhere in New Zealand is very <u>unlikely to be less than 5 $\mu g\ m^{-3}$</u> (except perhaps in the Central Otago high country), and also very <u>unlikely to be greater that 15 $\mu g\ m^{-3}$</u> (except in areas that are very close to exposed coasts following a very windy period or are very dusty or are severely affected by pollen).

A.5 Vehicle PM_{10} Emissions Reductions - 15%

The main vehicle emissions tool – the Ministry of Transport's NZ-TER database[8] – highlights that current technology trends will result in considerable reductions in PM_{10} emissions over the next 10 years. This is undoubtedly true and there is little doubt that the new vehicles appearing on the road do, and will continue to, have lower per vehicle emissions. However there is less confidence in two aspects (1) the reduction in PM_{10} emissions rates from diesels – particularly heavy duty trucks and buses, and (2) the increase in the size of the fleet and the vehicle kilometres travelled (VKT) in urban areas. The average age of a vehicle in 2005 in the fleet is 10.5 years, indicating that even by 2013 there will still be high emitters on the roads. On top of this are concerns about increasing congestion, road building, travel behaviour and other ways that traffic emissions might increase.

Examining traffic emissions projections from around the world provides some guidance on this issue. Figures used in Europe for 2005 to 2020 tend to be highly variable, from a relatively low 10-20% improvement in EU studies to a high reduction rate of 70% in the UK, and depend heavily on the pollutant in question. Some of the low rates are no doubt due to the fact that the vehicle emissions are already quite tightly controlled and obtaining further gains is harder. The higher rates are no doubt due to some very aggressive reductions

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[7] This was concluded under the HAPiNZ study, soon to be published and available at www.hapinz.org.nz .

policies in the UK and other places. In Australia, figures tend to be 30-45%, depending on the state and the source of the estimate.

Early ARC analysis, based on NZ-TER, estimated a 36% reduction for exhaust PM_{10} emissions. This is now regarded as somewhat optimistic due to the fraction of emissions from brake and tyre wear (still unknown in sufficient detail). The current Auckland air emissions inventory predicts a 15% reduction in transport PM_{10} emissions between 2005 and 2013 with business as usual policy, and this has been adopted as a realistic reduction in the absence of more aggressive policies. The effect of road dust is currently considered in the background PM_{10} concentration section.

A.6 Domestic Heating PM_{10} Emissions Reductions – 20%

New policy at both the local and national level is needed to reduce effects from burning wood and coal for home heating. This has been identified as one of the major target areas by many agencies. The main hope for reductions rests with the implementation of the new emissions standard of 1.5 g/kg for wood burners (supplemented by various other region-specific initiatives). If this were to be widely achieved, then it would have a dramatic effect on emissions. However industry experience indicates that the turnover rate can be slow to start, and perhaps not take full effect even by 2013. The expectations are that reductions in the first few years will be modest, accelerating as more of the older heaters are retired.

In addition, recent testing by Environment Canterbury[9] (under the Ministry for the Environment's Sustainable Management Fund scheme) suggests that some 1.5 g/kg standard heaters are capable of substantially higher emissions in real-world operating situations. This is of concern and another reason for caution in predicting reductions.

A.7 Industrial PM_{10} Emissions Reductions – 10%

This is a somewhat arbitrary figure that can obviously be improved upon if more specific information is available on any major industrial dischargers that are known to affect the region. It is a low rate of reduction, since many current consent holders will have terms that go beyond 2013, and for many new consents the best practice options will likely predominate over any additional requirements to meet standards. This factor is also low because many existing discharges do not have significant opportunities to reduce emissions, and in practice there will invariably be new dischargers consented in the region, even under the threat of compliance failures.

[8] Ministry of Transport, *New Zealand Transport Emissions Rate (NZ-TER) Database*, 2000.
[9] Real-life emissions from residential wood burning appliances in New Zealand. (2005) A.J. Scott. Sustainable Management Fund Report.