Review of Air Quality Monitoring Network Design

Expert Working Group Project 2
for the National Environment
Protection (Ambient Air Quality)
Measure Review

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Contents

1. Introduction

1.1 Background

The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM or NEPM) was made in 1998. The NEPM not only sets national air quality standards, it also provides a framework to support consistent air quality monitoring and reporting in Australia.

The National Environment Protection Council Service Corporation (NEPC) published the first review of the AAQ NEPM in 2011. The NEPM review provided an assessment of whether the NEPM is achieving its desired outcome of 'ambient air quality that allows for the adequate protection of human health and wellbeing'.

The review found that while the NEPM had provided a greater understanding of air quality in Australia and improved knowledge of the community health impacts of air pollution, there was now an opportunity for governments to act more strategically to manage and improve air quality, moving beyond strict compliance with standards to reducing population risk.

The overall finding of the NEPM review was that there are advantages to an integrated, risk-based approach to air quality management; however, the review also noted that achieving this new approach will be an evolutionary process requiring improvements in exposure assessment and changes in monitoring network design to support those assessments.

In mid-2015 the NEPC tasked an Expert Working Group (EWG) with assessing the feasibility of implementing the technical recommendations made by the NEPM review. The EWG grouped the recommendations into distinct projects and the NSW Government-led EWG Project 2 was to focus on NEPM review recommendations 10 and 11.

NEPM review recommendation 10

Redesign monitoring networks to represent population exposure on a pollutant-by-pollutant basis without compromising data collection for long-term trend analysis. A procedure to determine the location and number of sites similar to EU and/or US EPA is recommended.

NEPM review recommendation 11

Remove the population threshold and formula to enable monitoring on potential population risk rather than on population size.

1.2 Expert Working Group Project 2

The approach chosen for EWG Project 2 was to test some of the questions or assumptions implicit in the NEPM review recommendations 10 and 11. The questions posed by these recommendations were premised on assumptions that:

- current monitoring networks are inadequate to characterise population exposure and that this is due primarily to a lack of guidance on design
- there exists equivalent 'best practice' guidance internationally that Australia could use to redesign monitoring networks
- the current population threshold approach to designating minimum levels of monitoring assessments is an impediment to establishing population risk-based monitoring.

The monitoring section of the NEPM review (Attachment B) provides insights into the reasons for the NEPM review's recommendations for changes to monitoring design.

Given the above context, the primary deliverables of EWG Project 2 were to:

1. Review the current Australian guidance on monitoring network design and implementation.
2. Review current international best practice for monitoring network design.
3. Consolidate these findings into updated guidance material (see Attachment A – Project 2 work plan).

The first part of the project focused on reviewing the design and implementation of current Australian monitoring networks. The second part examined current international practice in monitoring network design, focusing on the United States Environmental Protection Authority (US EPA), the European Union (EU) and Canada. The third task of the project was to compare the current Australian approach to network design to what is perceived as 'best practice' internationally, with a view to updating the Australian guidance material where needed.

1.3 Summary of findings and recommendations

Project 2 has provided findings and recommendations which summarise the results of the two independent reports and provide guidance on improving monitoring network design.

1.3.1 Findings

1. The guidance on NEPM monitoring network design is comprehensive and often more comprehensible than other comparable international guidance material.
2. NEPM guidance on monitoring is flexible, allowing jurisdictions to monitor air quality anywhere. It does not restrict monitoring only to regions with populations over 25,000.
3. Most jurisdictions are meeting their NEPM monitoring requirements; however, population growth in some regions means that jurisdictions should re-assess monitoring requirements based on the latest available census data.
4. There is inconsistency in the designation of monitoring station types between jurisdictional monitoring plans and annual reports.
5. Monitoring for carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and lead (Pb) is probably adequate for all jurisdictions.
6. Additional ozone monitoring may be required in some inland and coastal regions to support screening of this pollutant.
7. Particle monitoring (PM_{10} and $PM_{2.5}$[1]) should be expanded (noting that the recent changes to the AAQ NEPM standards for particles require expanded $PM_{2.5}$ monitoring by 2018).
8. The benefits of using the Australian Bureau of Statistics (ABS) Significant Urban Area (SUA) population data rather than the Urban Centres and Localities (UCL) data for network design should be investigated.

[1] PM_{10} and $PM_{2.5}$ = particulate matter less than 10 microns and 2.5 microns, respectively

1.3.2 Recommendations

A number of recommendations have been made based on these findings. They follow clearly from the results of the independent reviews and present a transparent assessment of the consolidated review findings.

These recommendations should form the basis for updating the guidance on designing air quality monitoring networks. Some of the recommendations (for example, review frequency) may be incorporated into the NEPM directly.

The recommendations also suggest an approach to ensure that network design guidelines remain current, are sufficiently flexible to incorporate technical advances in air quality assessment and improved understanding of air quality impacts, and provide independent expert review of monitoring network implementation.

The final recommendation concerns a change to clause 14 of the NEPM, which addresses performance monitoring requirements.

Recommendation 1

Jurisdictional monitoring plans should be updated annually with changes documented clearly and transparently.

Recommendation 2

Jurisdictional monitoring plans should be reviewed and re-submitted every five years to ensure currency of population coverage and pollutant screening assumptions.

Recommendation 3

The population threshold of 25,000 to guide monitoring network design and NEPM assessments should be retained.

Recommendation 4

The Australian Bureau of Statistics Significant Urban Area (SUA) product should be the basis of population assessments for monitoring design.

Recommendation 5

Jurisdictions should re-assess their screening determinations at the earliest time practicable.

Recommendation 6

Jurisdictions should re-assess ozone monitoring requirements based on the updated 2007 screening procedures, focusing on large inland and coastal centres.

Recommendation 7

Screening procedures for $PM_{2.5}$ should be developed and screening procedures for PM_{10} should be updated to reflect changes in the NEPM, focusing on maximum PM_{10} levels excluding exceptional events.

Recommendation 8

An expert group should review trends in monitoring network design and advise jurisdictions on changes to monitoring design requirements. The group may also act as a review panel for monitoring plans.

Recommendation 9

Clause 14 of the NEPM should be amended to:

14 Number of performance monitoring stations

(1) The number of performance monitoring stations in a region should be based on a determination of the potential pollutant exposure risk to the region's population.

(2) Additional performance stations may be required to determine population exposure in high risk areas.

(3) Subject to subclauses (1) and (2), the minimum number of performance monitoring stations for a region with a population of 25,000 people or more must be the next whole number above the number calculated in accordance with the formula:

$1.5P+0.5$

where P is the population of the region (in millions).

2. Current NEPM monitoring network design

Each jurisdiction provided an NEPM monitoring plan for review by the NEPC in 2001 (with South Australia performing a review of their monitoring plan in 2005). The current networks operated in each jurisdiction differ from those proposed in the 2001 monitoring plans, as networks have evolved over time based on changes in population, the requirements of the NEPM, and based on the results of campaign monitoring and application of screening procedures. However, the justification for the changes in monitoring networks has often not been transparent to end users and the community.

Populations have increased, often significantly, since the submission of the 2001 monitoring plans (which were based upon 1996 census data) and the most recent census (2011).

The Peer Review Committee (PRC) guidance used the Australian Bureau of Statistics (ABS) product 'Urban Centres and Localities' (UCL), to provide the required population information in urban centres for the purposes of the NEPM. The ABS now provides more comprehensive census population products, including a 'Significant Urban Area' (SUA) product that considers the contiguous nature of urban development. If the population threshold of 25,000 remains within the NEPM, the benefits of using the SUA product, as opposed to the UCL product, should be investigated.

2.1 Network design criteria

As part of the initial decision to make the NEPM, the NEPC agreed to establish a Peer Review Committee (PRC) comprising nominees from industry and the environment movement, as well as from each jurisdiction, and supported by the NEPC Service Corporation. The PRC was established to assist jurisdictions to develop their monitoring plans to meet NEPM requirements, and to provide the NEPC with advice on the adequacy of those plans.

The PRC produced a set of technical papers to guide the development of jurisdictional monitoring plans, with the aim of assuring quality and national consistency. These guidance documents cover a broad range of issues that practitioners/ jurisdictions may experience in implementing the NEPM. The PRC technical papers provide a good platform to ensure a consistent approach across jurisdictions and are shown to be (i) comprehensive, and (ii) generally as clear, if not easier to interpret than similar guidance documents adopted by some other countries. They should ideally be read as a compendium of guidance documentation, given that a few issues are common across these technical papers.

A list of the most relevant PRC technical papers is presented below:

- Technical Paper No. 1 – Checklist for Monitoring Plans (May 2001)
- Technical Paper No. 2 – Selection of Regions (May 2001)
- Technical Paper No. 3 – Monitoring Strategy (May 2001)
- Technical Paper No. 4 – Screening Procedures (May 2001, rev. January 2007).

It is noted that the PRC technical papers are advisory only.

It is also noted that following the strategic and technical review of the NEPM (NEPC 2011), the NEPC recommended disbanding the PRC and replacing it with a working group or groups with a broader range of expertise to assist with scientific and technical matters (recommendation 19 of 23). These matters might include the future design of networks to better represent population exposure and exposure risk.

2.1.1 Checklist for monitoring plans

Technical Paper No. 1 (PRC 2001a) presents the framework for the development of monitoring plans and draws upon the information contained within most of the other technical papers. The technical paper seeks to guide the preparation of monitoring plans and to achieve consistency in structure and content across all jurisdictional plans.

Technical Paper No. 1 provides a checklist of items which should be covered in each monitoring plan. Monitoring plans should outline:

- selection of regions, consistent with Technical Paper No. 2
- monitoring requirements for each selected region, with reference to Technical Paper No. 3. This should include:
  - an appropriate description of the region
  - an evaluation of the number of performance monitoring stations (PMSs) required using the formula outlined in the NEPM subclause 14(1)
  - a description of the balance between trend and generally representative upper bound (GRUB) stations, and
  - evidence of appropriate screening where the number of PMSs is to be lower than that required
- siting of instrumentation and data handling, consistent with Technical Paper No. 6 – Meteorological Measurements (May 2001)
- accreditation of sites, with reference to Technical Paper No. 7 – Accreditation of Performance Monitoring (May 2001)
- reporting, consistent with Technical Paper No. 8 – Annual Reports (October 2002, rev. September 2010).

2.1.2 Selection of regions

Part 4, Section 14 of the NEPM states that air quality monitoring is required for regions with a population of 25,000 or more, although it does not restrict monitoring in regions with lower populations.

The NEPM defines ‘region’ as ‘an area within a boundary surrounding population centres as determined by the relevant participating jurisdiction’.

Technical Paper No. 2 (PRC 2001b) provides guidance as to how these regions should be selected. Three types of region are identified:

- **Type 1** a large urban or town complex with a population of 25,000 people or more requiring direct monitoring and contained within a single airshed
- **Type 2** a region with no one population centre with 25,000 people or more but with a total population of 25,000 or more, and with significant point source or area-based emissions as to require a level of direct monitoring
- **Type 3** a region with a population of 25,000 people or more but with no significant point or area-based emissions, so that ancillary data can be used to infer that direct monitoring is not required.

Selection of regions with >25,000 people is based on ABS data from the most recent census. Technical Paper No. 2 suggests that ABS UCL data appears to provide a transparent and well-defined option for the selection of regions. This is the approach adopted by all jurisdictions in selection of regions and should, therefore, represent a consistent approach.

Regions which are categorised in this way may also be amalgamated should there be enough evidence (such as monitoring data or dispersion modelling studies) that an airshed boundary encompasses more than one ABS urban centre. This amalgamation may be especially important in terms of secondary pollutants where concentration maxima may be experienced at significant distances from source (and from highly populated areas).

Regions categorised as Type 1 may be re-categorised as Type 3 regions with enough supporting evidence, such as a detailed review of each selected region, and with due consideration of pollution sources, meteorology and topography.

Regions with <25,000 people which together with other nearby urban centres result in population sizes >25,000, should be considered as Type 2 regions.

2.1.3 Monitoring strategy

Technical Paper No. 3 (PRC 2001c) outlines the strategy for air quality monitoring to satisfy the NEPM.

For clarity, it is first noted that in accordance with the PRC technical paper, all sites should be categorised as performance monitoring stations or PMSs, with sub-categorisation (by pollutant if required) as generally representative upper bound (GRUB), population-average or trend stations.

The general strategy requires PMSs to measure pollutants that may be experienced by most of the population (clause 14 of the NEPM). The aim of PMSs is to determine compliance within regions of major population. To achieve this adequately, the monitoring strategy makes it necessary to measure pollutants at the upper bounds of concentrations which may likely be experienced within a region. These stations are termed GRUB stations.

Monitoring plans must demonstrate an adequate balance of GRUB and population-average measurements. In regions where only one PMS is required, it is expected that the PMS will tend to be a GRUB site.

GRUB stations should be located in areas that are expected to experience relatively high pollutant concentrations, but at locations where pollutant gradients are generally low (i.e. avoiding the direct impacts of localised pollutant sources). These generally reflect the categorisation of ‘neighbourhood’ stations as defined within the Australian Standard (AS2922-1987 [superseded by AS/NZS 3580.1.1-2007]).

It is also necessary to ensure that an AAQ NEPM monitoring network provides widespread coverage of the populated area in a region. As such, population-average sites are located to ensure adequate monitoring of large portions of the populated area and of the total population within a region. Such sites may be required in addition to GRUB sites if these are located away from the major populated areas (in the monitoring of ozone for example).

The expectation of the PRC (PRC 2001c) was that ‘for an average urban area in Australia’ about 25,000 people would be living within a few kilometres of each monitoring station. It also states ‘moreover, stations will be located at sites where the pollutant gradients are generally low, so that they can represent the pollutant level across a substantial area and fraction of the population.’

The formula used in the calculation of total PMSs required (subclause 14(1) of the NEPM) may result in a lower number of sites than that required when considering GRUB and population-average sites.

The number of PMSs the NEPM requires in each identified region of >25,000 population is given by:

$$1.5P + 0.5$$

where *P* is the population (in millions).

Clause 15 of the NEPM also describes the use of trend stations that must be PMSs and be sufficient to monitor and assess long-term changes in ambient air quality in different parts of the jurisdiction. Trend stations must be operated for one or more decades.

The PRC guidance states that individual stations may monitor some pollutants in accordance with the GRUB concept and other pollutants as trend.

The use of campaign monitoring is outlined in Technical Paper No. 4 as a useful input into screening, although it is only identified in relation to GRUB monitoring locations.

2.1.4 Screening procedures

Subclause 14(3) of the AAQM NEPM states that 'Fewer performance monitoring stations may be needed where it can be demonstrated that pollutant levels are reasonably expected to be consistently lower than the standards mentioned in this Measure'.

The PRC has outlined a range of analyses that may be adopted to demonstrate this expectancy in a transparent manner within Technical Paper No. 4. These analyses are termed 'screening procedures' and are used to reduce the number of PMSs for a given pollutant below that determined using the formula outlined in subclause 14(1) of the NEPM, or to justify not monitoring a pollutant in regions with populations over 25,000.

The screening procedures were originally published in November 2000 (PRC 2000) and formed the basis of the monitoring plans submitted by each jurisdiction in 2001. A revision of the screening procedures was provided by the PRC in January 2007 which incorporated updated modelling results of NO_2 and O_3 (ozone) concentrations expected in regional centres and coastal locations.

Technical Paper No. 4 (PRC 2007) states:

- The maximum acceptance limit for any screening procedure, no matter how reliable, has been set at 75%, although adjustments have been made to account for background ozone. In other words, the PRC considers that performance monitoring (or an approved alternative under subclause 11(b)) should occur within a region if pollutant concentrations more than 75% of the standard are probable.

  This is in accord with the intent of subclause 14(3).
- To maintain a conservative approach, except for PM_{10}, the maximum predicted or measured concentration in the period specified should be used for comparison with acceptance limits, even if the NEPM goal may specify number of exceedances.
- For pollutants which have standards for more than one averaging period, the acceptance limit to be used is that of the standard which is most difficult to meet in any given region. In many cases, this may involve the shortest averaging period.

In the case of PM_{10}, given the update of the NEPM relating to numbers of exceedances allowed (previously five, now zero), the screening procedures should consider maximum concentrations of PM_{10}, or consider the impacts of exceptional events.

Minor updates to Technical Paper No. 4 relate to ambiguities in the number of years of monitoring data to apply for specific methods. The significant updates relate to a dispersion modelling assessment of the likely population limits of inland and coastal towns which may demonstrate compliance with the NO_2 and O_3 acceptance limits for Procedures E and F.

2.2 Monitoring plans

The following section briefly describes the monitoring networks proposed by each jurisdiction in 2001 and examines the network as described within the most recent NEPM monitoring report. A critical review of the current NEPM monitoring network is provided with respect to:

- population coverage
- the selection and current designation of monitoring stations within the NEPM framework
- the current validity/adequacy of regions selected for compliance monitoring and the currency of ABS population classifications
- the validity of regional monitoring requirements with respect to pollutants measured, instrumentation used, and screening procedures used.

There is no requirement in the NEPM for monitoring plans to be updated at any prescribed frequency. The requirement for reporting outlined in clause 18 of the NEPM does require that each jurisdiction submit an annual report outlining compliance with the NEPM, and any changes to the monitoring networks are generally documented and discussed within these reports.

Changes in populations in particular and pollutant sources (locations and emissions intensity) within each jurisdiction are not reviewed in annual reports at the level of detail required by the PRC technical papers relating to monitoring plans. There is, therefore, a risk that changes in population and pollution sources, in addition to the changes in the NEPM and PRC technical notes (as detailed in the preceding sections), may be inadvertently overlooked.

This review assesses the validity of current jurisdictional monitoring plans, as documented in these plans and as determined through a review of the most recent annual report.

2.2.1 New South Wales

Ambient air quality monitoring has been performed in Sydney and Newcastle since the early 1950s. In recent years there has been a significant expansion in the NSW air quality monitoring network (AQMN) operated by the Office of Environment and Heritage (OEH) and a diversification of the purpose, funding arrangements and reporting requirements for air quality monitoring. These changes are partly a result of population and industry growth, changing technology, and changing community expectations.

The requirements for air quality monitoring and the information provided by the monitoring networks is diverse. One purpose of air quality monitoring both in New South Wales and in all jurisdictions is to provide information in accordance with the NEPM.

Air quality monitoring in New South Wales consists of monitoring undertaken by, funded by, or required by OEH or the Environment Protection Authority (EPA) including: the NSW Government funded Statewide Air Quality Monitoring Network (SAQMN – 26 stations); and industry-funded networks in the Upper Hunter Valley (UHAQMN – 14 stations) and the Newcastle Local Government Area (NLAQMN – 3 stations).

The NSW NEPM-designated monitoring stations are a subset of the SAQMN.

The NSW air quality monitoring network has been developed over many decades and has provided useful information on air quality trends and assessment of compliance with relevant regulations during that period.

The NEPM monitoring plan for New South Wales (NSW OEH 2001) was submitted to the NEPC in June 2001. Based on 1996 census data for Urban Centres and Localities, 15 urban centres triggered the population threshold of >25,000. Although Coffs Harbour only registered a population of 22,000 in 1996, its proximity to Sawtell (population 13,000) resulted in a region with a population of over 35,000. These 16 urban centres were grouped into 15 regions, selected by NSW OEH using the definition of ‘region’ provided by the PRC (PRC 2001b).

The NSW monitoring plan classifies monitoring stations as either performance (P), trend (T) or campaign (C). Trend sites are noted to be ‘generally representative of regional population exposure and generally approximate the PRC GRUB station definition’. It is not clear whether a ‘regional population exposure’ equates to the definition of ‘population-average’ stations as defined in (PRC 2001c).

The New South Wales 2014 NEPM report states (NSW OEH emphasis):

> OEH characterises the air quality to which the general population is exposed in a region by monitoring all air pollutants of interest at a network of trend stations. These stations capture the majority of pollution events that occur from time to time, but their role is supplemented by that of additional permanent upper bound stations (performance stations) where selected pollutants are monitored to ensure that all major pollutant events are captured and reported. Campaign monitoring is also done in regional centres at Albury, Wagga Wagga North, Bathurst and Tamworth.

There is some discrepancy in the classification of monitoring stations between the monitoring plan and most recent monitoring report, where trend stations are classified as GRUB stations

in the 2001 monitoring plan, and performance stations noted as serving this purpose in the 2014 report.

Between 2001 and 2014, several changes occurred with respect to the NEPM monitoring network in New South Wales, including:

- The number of PMSs serving the Sydney region reduced from 12 (including proposed and operational) to 11. The NEPM requires a minimum of seven PMSs based on 2011 population data.
- A PMS specific to the Central Coast region (Wyong) was commissioned in 2012 (identifying the Central Coast as a distinct region for NEPM monitoring purposes).
- The proposed site at Maitland (Lower Hunter region) was not commissioned.
- The number of PMSs in the Illawarra region reduced from four to three. The NEPM requires a minimum of one PMS based on 2011 population data.
- No monitoring for NEPM purposes is performed in the Upper Hunter.
- Monitoring in regional New South Wales is limited to four locations (Albury, Bathurst, Tamworth and Wagga Wagga).
- The proposed campaign monitoring of PM_{10} at Orange, Dubbo and Lismore was not commissioned.
- $PM_{2.5}$ monitoring is proposed at all 26 NEPM monitoring stations across New South Wales.

2.2.2 Australian Capital Territory

Ambient air quality monitoring is performed in the Australian Capital Territory (ACT) to support both the NEPM and an air quality index (AQI) to provide effective communication of the ambient air quality conditions to the ACT community.

ACT Health, through the Health Protection Service (HPS), is the agency responsible for maintaining and providing air quality data to the Environment and Sustainable Development Directorate (ESSD). ESDD is responsible for submitting the NEPM annual reports to the NEPC. ACT Health operates the territory's air quality monitoring network, which comprises two NEPM PMSs in Monash and Florey, and a smaller station in Civic.

ACT Health monitors CO, NO_2, O_3, PM_{10} and $PM_{2.5}$. Due to a lack of heavy industry the ACT does not monitor SO_2 for the NEPM and following the phase-out of leaded fuel on 1 January 2002, the ACT ceased monitoring Pb in July 2002.

PM_{10} and $PM_{2.5}$ are the pollutants of most concern in the ACT. Elevated levels of particulate matter can arise in colder months, for example, due to smoke emitted from domestic wood heaters. Elevated levels may also occur from bushfire and burn-off events in and around the ACT.

The ACT NEPM monitoring plan (ACT Government 2001) was submitted to the NEPC in January 2001. Based on the population threshold of 25,000 only one region required monitoring (Canberra, Type 1 region with 311,000 population). Five of the six criteria pollutants were identified to be measured with the need for SO_2 monitoring screened out due to a lack of significant industrial sources within Canberra. The Monash station was nominated to be both a PMS and a trend station.

Civic monitoring station though commissioned, was not nominated for use as an NEPM monitoring station in the 2001 monitoring plan and flagged for relocation due to redevelopment pressures. As described in the 2009 annual monitoring report, the ACT population had increased above the threshold where a second NEPM monitoring station was required. Civic station was nominated to be used for this purpose (for CO, O_3 and NO_2 only).

The 2014 NEPM monitoring report for the ACT identifies that there are currently three PMSs operational, although no indication of whether these are GRUB, trend or population-average

stations is provided. Given the population increase to 356,000 in the 2011 census, the required number of PMSs is two.

The Civic monitoring station is not compliant with the requirements of the relevant Australian Standard (AS/NZS 3580.1.1 Methods for sampling and analysis of ambient air Part 1.1: Guide to siting air monitoring equipment). A newer station has been commissioned at Florey (commissioned February 2014). The Civic monitoring station measures only PM_{10} and O_3 and is assumed to be decommissioned (for NEPM monitoring purposes) at some point. $PM_{2.5}$ is measured at two of the NEPM monitoring stations.

The number and location of monitoring stations in the ACT is adequate at present to meet the requirements of the NEPM.

2.2.3 Northern Territory

The Northern Territory (NT) monitoring plan (NT Government 2001) identified one urban area requiring monitoring, being Darwin with a population of 70,000 based on the 1996 census. The next largest region was Alice Springs with a population of about 22,000 in 1996.

Monitoring in Darwin was proposed at one station at Darwin Airport measuring PM_{10} only. The station was proposed to be a PMS and GRUB station. The lack of monitoring of CO, SO_2 and Pb was justified through the application of screening procedures and assessment of the requirement for monitoring of NO_2 and O_3 was to be performed following review of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) TAPM consultancy (used in the updated screening procedures (PRC 2007)).

Since the 2001 monitoring plan was submitted, the NT EPA has identified the population of Alice Springs as exceeding the population threshold of 25,000 (c.28,000 population). Although monitoring is not currently performed in Alice Springs, NT EPA intends to conduct monitoring in future years.

The 2014 monitoring report for the Northern Territory identifies that two stations are now operational for the purposes of assessment against the NEPM: Winnellie and Palmerston. Winnellie performs the role of a PMS, trend and GRUB station and Palmerston a PMS only. All pollutants other than lead (including $PM_{2.5}$) are monitored at these stations.

The number of monitoring stations is adequate at present to meet the requirements of the NEPM (based on 2011 census data); however, it is recommended that an assessment of the population of Alice Springs is performed to ensure it is accurately quantified.

2.2.4 Queensland

The Queensland (QLD) 2001 monitoring plan (QLD EPA 2001) submitted to the NEPC identified 10 regions incorporating approximately 15 urban areas. Monitoring was proposed at nine stations within the SE Queensland region, at one station in Gladstone and one in Mount Isa. Campaign monitoring was proposed in the remaining seven regions (and campaign monitoring of O_3 at Gladstone). Screening procedures were used to justify a reduction in the number of PMSs for SO_2, CO and Pb in the SE Queensland and Gladstone regions, and for CO and Pb in the remaining regions, apart from Toowoomba where CO monitoring was proposed.

Since the 2001 monitoring plan, there have been no changes to the categorisation of regions, with the same number of areas requiring NEPM monitoring. These areas are still defined by the QLD Department of Environment and Science as in the 2001 monitoring plan. Populations in these areas have increased since the 1996 census although the required number of monitoring stations remains the same. The population within the SE Queensland region should be confirmed based on 2011 census data as the populations covered by the regional definition are not entirely transparent in the 2001 monitoring plan. Additionally, the

areas of Caloundra, Mooloolaba and Maroochydore are seemingly incorporated into the Sunshine Coast UCL product in the 2011 census.

The 2014 annual monitoring report for Queensland includes six stations in the SE Queensland region, three within Townsville, and one each in Mackay and Gladstone. Screening arguments have been used to justify the lack of monitoring within regional centres for a few pollutants. Of note is the justification provided for a lack of O_3 monitoring in:

- Bundaberg (coastal, population 50,000 in 2011)
- Gladstone (coastal, population 32,000 in 2011)
- Mackay (coastal, population 74,000 in 2011)
- Maryborough/Hervey Bay (coastal, population 53,000 in 2011)
- Mount Isa (inland, population 21,000 in 2011)
- Toowoomba (inland, population 97,000 in 2011)
- Townsville (coastal, population 158,000 in 2011).

The justification provided relates to Technical Paper No. 4 (PRC 2007) which states that based on modelling studies, inland centres with populations <25,000 and coastal centres with populations <62,000 may not require monitoring of ozone; however, the populations of Mackay, Toowoomba and Townsville exceed this population-based criterion and further justification for the lack of ozone monitoring in these regions is required.

$PM_{2.5}$ is measured at three of the NEPM monitoring stations across Queensland, two of which are located within Brisbane. The minimum number of PMSs required within Brisbane alone is four. No justification could be identified for reducing the number of $PM_{2.5}$ monitoring stations although it is noted that jurisdictions have until June 2018 to report $PM_{2.5}$ exposure annually.

The 2014 annual monitoring report for Queensland includes the station designations of 'population-average' and 'GRUB', which were not identified in the 2001 monitoring plan. The number of monitoring stations is generally adequate at present to meet the requirements of the NEPM; however, the screening arguments for O_3 (and NO_2) should be reviewed either in the light of O_3 monitoring performed elsewhere in the State, or using the updated screening procedures as outlined in PRC Technical Paper No. 4 (PRC 2007).

In addition to the air quality monitoring performed to satisfy NEPM requirements, the QLD Government does perform additional monitoring to assess the impact of ports, industry, coal mining and other impacts on air quality within the State. This additional monitoring is performed in SE Queensland, Gladstone, Mackay, Townsville and Mt Isa. Although NEPM monitoring is performed in each of these areas, additional monitoring is performed to assess the impacts of specific activities on nearby residential areas.

Industrial operators also operate their own air quality monitoring networks in Queensland.

2.2.5 South Australia

The South Australia (SA) monitoring plan (SA EPA 2005) was reviewed in 2005 and is referenced in this report. The 2005 monitoring plan identified one urban area of ≥ 25,000 population which required air quality monitoring (Adelaide). In addition, the urban area of Mt Gambier (although with a population of 24,000 in 2005) and the region identified as Spencer (incorporating Port Pire, Port Augusta and Whyalla) were both identified as Type 2 regions warranting monitoring based on the level of industry present.

Monitoring in each of the three regions was proposed at seven PMSs within the Adelaide region, one in the Mt Gambier region and four in the Spencer region. Screening procedures were used to justify not monitoring O_3, SO_2, NO_2, CO and Pb at certain sites in Adelaide, CO and Pb in Mt Gambier, and O_3, NO_2, CO, PM_{10} and Pb at certain sites in the Spencer region.

Since the 2005 monitoring plan was submitted to the NEPC, there have been no changes to the categorisation of regions. The Mt Gambier region is shown to meet the population threshold of 25,000 and warrants an NEPM monitoring station through application of subclause 14(1) of the NEPM, although the station in this location is no longer operational. No justification for cessation of monitoring in this location is provided. Populations in the Spencer region have reduced by approximately 4000 although one PMS is still required.

The concept of GRUB stations is included in the 2013 monitoring report, not having been discussed in the 2005 monitoring plan. $PM_{2.5}$ monitoring is performed at two monitoring stations within Adelaide.

The number of monitoring stations is adequate at present to meet the requirements of the NEPM, although the justification for ceasing monitoring in Mt Gambier should be clarified.

In addition to the air quality monitoring performed to satisfy NEPM requirements, the SA Government does perform additional monitoring from time to time to assess certain issues (such as SmokeWatch in the Adelaide Hills).

Some industries also perform their own air quality monitoring programs although these are separate from SA EPA monitoring activities.

2.2.6 Tasmania

The Tasmania (TAS) monitoring plan (TAS DPIWE 2001) identified three regions of ≥25,000 population which required air quality monitoring. The Hobart region included the Kingston–Blackmans Bay, Bridgewater–Gagebrook and New Norfolk urban areas, Launceston region included George Town, and Devonport included the Latrobe urban area.

NEPM monitoring was proposed at two stations within the Hobart region, one station in Launceston and one station in Devonport (campaign monitoring only).

Screening procedures were used to justify the lack of monitoring for O_3, NO_2, and Pb in all regions with further screening performed for SO_2 (in Launceston) and CO (in Launceston and Devonport).

Since the 2001 monitoring plan was submitted to the NEPC, there have been no changes to the categorisation of regions, with the same number of areas requiring monitoring. These areas are still defined by EPA Tasmania as in the 2001 monitoring plan. Populations in these areas have increased since the 1996 census; however, the required number of PMSs in each region remains unchanged.

The 2013 annual monitoring report for Tasmania provides arguments for screening of O_3, NO_2, CO, SO_2 and Pb based on campaign monitoring of these pollutants. $PM_{2.5}$ is measured at three of the NEPM monitoring stations.

The number of monitoring stations is adequate at present to meet the requirements of the NEPM.

Since 2009 EPA Tasmania has also operated the Base Line Air Network of EPA Tasmania (BLANkET). This network consists of 29 air quality monitoring stations which report near real-time indicative particulate (PM_{10} and $PM_{2.5}$) concentrations.

The purpose of the BLANkET network is to obtain particulate data away from the main monitoring stations in Hobart, Launceston and George Town and to monitor the spatial extent of smoke impacts from planned (and unplanned) bushfire burn events. Some stations are located to allow assessment of the impact of domestic wood heaters and to provide a measure of general air quality across Tasmania.

The data collected by the BLANkET network are indicative only, as they are not collected using reference methods (as per the NEPM monitoring network). The method used to collect these indicative data is a DRX DustTrak, which uses a light-scattering laser photometer. These data are relatively low-cost to collect with equipment purchase, deployment and maintenance costs significantly lower when compared to costs associated with running the

NEPM monitoring network sites. This allows a much larger network to be operated and provides EPA Tasmania with information relating to particulate concentrations across a larger portion of the state than that covered by the NEPM monitoring network.

BLANkET may provide a good model for other Tier-2 type monitoring networks.

2.2.7 Victoria

The Victoria (VIC) monitoring plan (EPA Victoria 2001) identified eight regions with populations ≥25,000 requiring air quality monitoring. The Melbourne, Geelong and Melton urban areas were classified as belonging to the Port Phillip region, with the five remaining areas classified as individual regions for the purposes of NEPM monitoring. VIC EPA also nominated Mildura (population of 24,000 in 1996) and the Latrobe Valley (incorporating Traralgon, Morwell, Moe and Warragul – combined population of 130,000) as requiring NEPM monitoring.

Monitoring in each of the eight regions was proposed at 13 stations within the Port Phillip region and at two stations within the Latrobe Valley. No monitoring within any of the other regions was proposed, other than campaign monitoring of PM_{10} in each of the regional centres and the use of NSW EPA air quality measurements in Wodonga (Albury–Wodonga). Screening procedures were used to justify not monitoring O_3, NO_2, CO and Pb in the regional centres.

Since the 2001 monitoring plan was submitted to the NEPC, there have been no changes to the categorisation of regions, with the same number of areas requiring NEPM monitoring. These areas are still defined by VIC EPA as in the 2001 monitoring plan. Populations in these areas have increased since the 1996 census, however, with the required number of PMSs in the Port Phillip region increasing from five to seven. Campaign monitoring has been performed in Ballarat, Bendigo, Shepparton, Warrnambool and Mildura.

The 2014 annual monitoring report for Victoria includes the station designations of ‘population-average’ and ‘GRUB’, which were not identified in the 2001 monitoring plan.

$PM_{2.5}$ monitoring is performed at two NEPM monitoring stations in the Port Phillip region. Nine PMSs will be required prior to June 2018.

The number of monitoring stations is probably adequate at present to meet the requirements of the NEPM; however, while campaign monitoring for PM_{10} has occurred in some regional areas, attention should be given to performing the updated screening assessment for ozone (especially). This recommendation considers the updated ozone screening procedure identifying inland towns ≥25,000 as potentially experiencing ozone episodes and is made in light of monitoring results at Traralgon (66% of the 1-hr criterion, averaged over the last five years).

VIC EPA also operates several portable instruments to measure $PM_{2.5}$ concentrations. These methods include Beta Attenuation Monitors (BAM) which is an approved reference method, and more portable instruments such as the DustTrak and ADR 1500, both of which employ a light-scattering laser photometer to obtain information on aerosol concentrations.

2.2.8 Western Australia

The Western Australia (WA) monitoring plan (WA DER 2001) identified five regions of ≥25,000 population that required consideration for air quality monitoring. Monitoring in each of the regions was proposed with five stations in Perth, and one station in each of the other regions. A reduction in the number of pollutants monitored at certain stations was justified using screening procedures. NEPM monitoring stations were also proposed in Kalgoorlie and Mandurah.

Since the 2001 monitoring plan was submitted, several changes have occurred in Western Australia. Populations and definitions of regions have changed, and the number of PMSs required in some regions has changed. Of note is the inclusion of Mandurah within the Perth

urban area (rather than a separate entity in the 1996 census), and the inclusion of Albany, Busselton and Ellenbrook as regions of ≥25,000 population.

The 2014 annual monitoring report for Western Australia generally addresses the issues of increasing populations with additional monitoring stations commissioned in Albany (in July 2006) and Busselton (in November 2006). The report includes a few stations categorised as 'DER' which indicates that these stations 'will be maintained by DER for the foreseeable future'.[2] Although included in the compliance report for 2014, it is not entirely clear whether these stations, or measurements at certain stations are part of the overall strategy to meet the requirements of the NEPM or are part of a broader air quality monitoring strategy (or both). These 'DER' measurements are applicable to $PM_{2.5}$ currently monitored at six stations.

The number of monitoring stations is adequate at present to meet the requirements of the NEPM; however, monitoring might be considered for Kalgoorlie and in Mandurah. No monitoring of O_3 or NO_2 is performed outside of the Perth urban area and further consideration should be given to the updated PRC screening procedures (PRC 2007) in light of the monitoring results for O_3 at Caversham (90% of the NEPM 1-hr criterion, averaged over the last five years), and the updated screening procedure identifying inland towns ≥25,000 as potentially experiencing O_3 episodes. It is likely that NO_2 concentrations measured within the Perth urban area are sufficient to not require monitoring of NO_2 outside of Perth, although DER has identified that monitoring of NO_X and O_3 concentrations is of use for emissions inventory and dispersion model validation studies.

2.3 Discussion

The review of current jurisdictional monitoring networks and formally lodged monitoring plans highlighted some common discrepancies across jurisdictions. These included a failure of jurisdictions to formally revisit (or document) the assessments of monitoring requirements based on population criteria and to adequately or consistently designate monitoring station types.

Jurisdictions have not routinely updated their monitoring plans, many of which are outdated (Table1).

Table 1 NEPM monitoring plans – summary

Jurisdiction	Most recent plan	Planned regions (stations)	Current regions (stations)	Comments
NSW	Jun 2001	11 (17)	8 (25)	Significant monitoring expansions since 2010
ACT	Jan 2001	1 (1)	1 (3)	No current station designation
Northern Territory	May 2001	1 (1)	1 (2)	Alice Springs population may need reassessment
Queensland	Jun 2001	12 (17)	5 (13)	Regional monitoring needs reduced by screening
South Australia	May 2005	3 (12)	2 (9)	Most recent plan of all jurisdictions
Tasmania	May 2001	3 (4)	3 (3)	Additional monitoring through BLANkET network

[2] In July 2017 the former WA Department of Environment Regulation (DER) became the Department of Water and Environment Regulation (DWER).

Jurisdiction	Most recent plan	Planned regions (stations)	Current regions (stations)	Comments
Victoria	Nov. 2001	8 (15)	2 (12)	Additional monitoring planned
Western Australia	May 2001	5 (9)	8 (13)	Including six $PM_{2.5}$ stations

2.3.1 Population estimates

Most monitoring plans were lodged in 2001 with regional population assessments based on the 1996 census. An assessment of regional populations based on 2011 census data highlighted that monitoring in some regions will need to be expanded for adequate population coverage. The release of the 2016 census data during 2017 will mean that most jurisdictional monitoring plans are now based on population data that is 20 years old. Also, since the PRC Guidance new population products are available from the ABS.

The review found that clearer guidance is required on estimating population for network design purposes; for example, the review of Northern Territory monitoring showed that based on the 2011 census data for the UCL product, the population of Alice Springs was approximately 24,000, while the SUA census product identifies the population of Alice Springs as over 25,000 in 2011.

The use of SUA data may be appropriate for all jurisdictions (although it is not the method outlined within (PRC 2001b)). An SUA is defined as (ABS 2015):

> clusters of one or more contiguous Statistical Area Level 2 (SA2) containing one or more related urban centres joined using the following criteria:
>
> - they are in the same labour market
> - they contain related urban centres where the edges of the urban centres are less than 5 kilometres apart defined by road distance
> - they have an aggregate urban population exceeding 10,000 persons
> - at least one of the related urban centres has an urban population of 7000 persons or more.

The use of SUA data can result in significant increases in population, for example, the Bowral–Mittagong SUA (NSW) is shown to include a population of ~35,000 in 2011 where the UCL product only indicates a population of ~20,000. The selection of the statistical product used to define areas/regions requiring monitoring is clearly an issue for investigation.

3. International practice in network design

An independent review was commissioned to examine current international practice in monitoring network design, focusing on the United States Environmental Protection Agency (US EPA), the European Union (EU) and Canada.

Specifically, the review was tasked with providing information that could assist with determining if equivalent 'best practice' guidance exists internationally that Australia could use to redesign monitoring networks.

The review provided a succinct 'landscape' view of international best practice in air quality monitoring network design. It included an assessment of monitoring networks with similar aims to the NEPM in countries/regions within similar socio-economic levels of development (i.e. members of the OECD).

The review considered guidance on design criteria that included:

- site selection (population coverage, spatial extent)
- the number of stations required
- screening criteria
- network review processes.

3.1 United States of America

The key legislation in the United States of America regarding the design of ambient air quality monitoring networks is the *Clean Air Act (2004)*.

The Clean Air Act (CAA) requires each state to submit a State Implementation Plan (SIP) for the implementation, maintenance, and enforcement of each primary or secondary National Ambient Air Quality Standard (NAAQS). The NAAQSs cover similar pollutants to the NEPM, (i.e. CO, Pb, NO_2, O_3, PM_{10}, $PM_{2.5}$ and SO_2), but with some differences in averaging times and target concentrations between the NAAQS and the NEPM (e.g. ozone).

3.1.1 Monitoring networks

The Clean Air Act requires 'Ambient Air Quality Surveillance' be addressed by each State (or local agency) in an annual monitoring network plan that provides for the establishment and maintenance of an air quality surveillance system that consists of:

- **NCore:** National Core multipollutant monitoring stations measure particles ($PM_{2.5}$, speciated $PM_{2.5}$, $PM_{10-2.5}$), O_3, SO_2, CO, nitrogen oxides ($NO/NO_2/NO_Y$), Pb and meteorology. NCore measures multiple pollutants in order to provide support to integrated air quality management data needs. NCore sites include both 'neighbourhood' and 'urban' scale measurements in general, in a selection of metropolitan areas and a limited number of more rural locations.

  Continuous monitoring methods are to be used at NCore sites when available for a pollutant to be measured, as it is important to have data collected over common time periods for integrated analyses. NCore multipollutant sites are intended to be long-term sites useful for a variety of applications including air quality trend analyses, model evaluation, and tracking metropolitan area statistics.
- **SLAMS:** State or Local Air Monitoring Stations make up the ambient air quality monitoring sites that are primarily needed for NAAQS comparisons, but may serve other, further purposes. SLAMS exclude special purpose monitor (SPM) stations and include NCore, Photochemical Assessment Monitoring Stations (PAMS), and all other state or locally operated stations that have not been designated as SPM stations.
- **STN:** Speciation Trends Network comprises $PM_{2.5}$ speciation stations, providing chemical species data of fine particulates.

- **SPM:** Special Purpose Monitor stations are designated as special purpose stations in the US EPA's monitoring network plan and in the Air Quality System. The US EPA does not count these stations when showing compliance with the minimum requirements of this subpart for the number and siting of monitors of various types.
- **PAMS:** Photochemical Assessment Monitoring Stations are required in serious, severe and extreme ozone nonattainment areas.

The CAA details requirements for a number of areas to be addressed in annual monitoring plans including network design criteria, and site locations relevant to local conditions.

The various monitoring networks must be designed to deliver the objectives for the monitoring, including providing information to communities, reporting compliance with ambient air quality standards, emission control programs and providing data for research on human health and environmental management.

Monitoring requirements for networks vary and may include measurement of:

- the peak concentrations anticipated across an area
- typical exposure rates for a community
- pollution associated with source-specific emissions
- general background concentrations
- regional or transboundary pollution transport
- non-human health impacts, such as welfare impacts, vegetation, visibility, etc.

3.1.2 Population criteria

Population thresholds play a significant role in the determination of the required number of monitoring stations within each of the networks.

For the SLAMS network (the networks most similar to the NEPM) population is the key consideration for determining the number of monitoring stations required by a jurisdiction. The population thresholds vary by pollutant and NAAQS threshold levels:

- One CO monitor is required to be co-located with a near-road NO_2 monitor in all Core Based Statistical Areas (CBSAs) with a population of 1,000,000 or more. For clarity, this is a core area of a population of 10,000 or more with adjacent centres having a high degree of economic and/or social interaction with the core (similar to the ABS SUA).
- At least one near-road NO_2 monitoring station is required in each CBSA with a population of 500,000 or more. An additional monitoring location is required for a CBSA with a population over 2,500,000 or, if there is a roadway section with an annual average daily traffic (AADT) count of 250,000 vehicles or more.
- At least one SO_2 monitor is required per CBSA with additional monitors determined based on a population weighted emissions index.
- PM_{10} monitoring requirements are based on population and maximum observed concentrations. At least one PM_{10} monitor is required per CBSA >500,000 people.
- $PM_{2.5}$ monitoring is based on population and observed concentrations with at least one monitor per CBSA >500,000 people and at least one per CBSA >50,000 if concentrations are above 85% of the NAAQS.
- At least one O_3 monitor is required per CBSA of >350,000 people.

3.1.3 Spatial scales

Each state is required to operate at least one NCore site, although this may increase depending on the number of distinct airsheds and the corresponding spatial variability of the respective pollutant(s).

Spatial scales for the SLAMS networks vary by pollutant, from roadside (<0.1–0.5 km), neighbourhood (>0.5–4 km), urban (4–50 km) and regional (10s to 100s of km) (Table 2).

Table 2 Relationship between site types and scales of representativeness

Site type	Siting scales (including typical representative scales)					
	Micro	Middle	Neighbourhood	Urban/Rural	Regional	National
	<100 m	100 m–0.5 km	0.5–4 km	4–50 km	10/100s of km	National
Highest concentration	✓	✓	✓			
Highest concentration (secondary pollutants)				✓	✓	
Population orientated			✓	✓		
Source impact	✓	✓	✓			
General/background & regional transport				✓	✓	✓
Welfare-related impacts				✓	✓	

3.1.4 Screening criteria

The SLAMS networks allow for fewer monitoring stations for some pollutants based on observed concentrations relative to the NAAQS.

For PM_{10} the thresholds are <80% of the NAAQS for low concentration designation through to >120% of the NAAQS for high concentration designation. The $PM_{2.5}$ threshold is 85% of the NAAQS while the ozone threshold is 80% of the NAAQS. Levels below these thresholds can determine fewer required monitoring stations (after accounting for CBSA population).

A summary of the population and concentrations thresholds, together with the spatial scaling factors for each of the networks and pollutants, is provided in Table 3.

3.1.5 Review

The US EPA requires a number of plans to be submitted annually including plans for:

- establishing/maintaining NCore multipollutant stations
- source-orientated Pb monitoring sites for sources emitting greater than 0.5 ton/y of Pb
- area-wide NO_2 monitoring to protect human health and reduce exposure risk
- roadside NO_2 monitoring to protect human health and reduce exposure risk
- SO_2 and CO monitoring
- PM_{10} and $PM_{2.5}$ monitoring
- O_3 monitoring
- Photochemical Assessment Monitoring Stations (PAMS).

The State Implementation Plan and annual plans must include a statement of purposes for each monitor and evidence that siting and operation of each monitor meets the requirements of the CAA for: quality assurance, health and safety, data capture, measurement uncertainty, and other ‘operational’ considerations; approved and designated air quality monitoring methodologies; network design criteria; and site location, relevant to local conditions.

Table 3 United States network design – summary

Network	Pollutant	Purpose	Scaling factors(a)				Minimum thresholds	Spatial scales(b)					
			Pop	BG	Source	Spat		all	mic	mid	nei	urb	reg
USEPA SLAMS	CO	roadside					pop ≥1,000,000, co-located w/NO_2		✓	✓			
	NO_2	roadside	✓		✓		pop ≥500,000, AADT ≥250,000		✓				
		population					pop ≥1,000,000				✓	✓	✓
	SO_2	PWEI	✓		✓		PWEI ≥5,000	✓					
	PM_{10}	population	✓	✓			pop ≥100,000 w/background >120% standard			✓	✓		
		population	✓	✓			pop ≥250,000 w/background >80% standard			✓	✓		
		population	✓	✓			pop ≥500,000 w/background <80% standard			✓	✓		
	$PM_{2.5}$	population	✓	✓			pop ≥50,000 w/background >85% standard				✓		
		population	✓	✓			pop ≥500,000 w/background <85% standard				✓		
	O_3	population	✓	✓			pop ≥350,000 w/background <85% standard				✓	✓	✓
	Pb	source					industry ≥0.5 tpa, airports ≥1.0 tpa		✓	✓			
USEPA NCore	CO	population					1 per state				✓	✓	✓
	NO_X	population					1 per state				✓	✓	✓
	SO_2	population					1 per state				✓	✓	✓
	$PM_{2.5}$	population					1 per state				✓	✓	✓
	$PM_{10-2.5}$	population					1 per state				✓	✓	✓
	O_3	population					1 per state				✓	✓	✓
	Pb	population					1 per state pop ≥500,000				✓	✓	✓
USEPA PAMS	VOCs	population					1 per state pop ≥1,000,000				✓	✓	✓
	O_3	population					1 per state pop ≥1,000,000				✓	✓	✓
	NO_X	population					1 per state pop ≥1,000,000				✓	✓	✓
	NO_Y	population					1 per state pop ≥1,000,000				✓	✓	✓

Notes: (a) Scaling Factors: pop – requirements are scaled by population; BG – requirements are scaled by background pollutant concentrations; Source – requirements are scaled by source emissions; Spat – requirements are scaled by spatial considerations. (b) Spatial scales: mic – micro; mid – middle; nei – neighbourhood; urb – urban; reg – regional

3.2 European Union

The *Air Quality Framework Directive* on ambient air quality assessment and management (96/62/EC) was adopted by the European Council in September 1996. Supplementing the directive were a series of 'daughter' directives:

- Council Directive 1999/30/EC of the European Parliament and of the Council relating to limit values for sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (First Daughter Directive)
- Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air (Second Daughter Directive)
- Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air (Third Daughter Directive)
- Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (Fourth Daughter Directive).

Subsequently, the Framework Directive and the first, second and third daughter directives have been brought together under the Ambient Air Quality and Cleaner Air for Europe (CAFE) Directive (2008/50/EC).

The objectives of the CAFE Directive are summarised in Article 1 as:

- defining and establishing objectives for ambient air quality designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole
- assessing the ambient air quality in Member States on the basis of common methods and criteria
- obtaining information on ambient air quality in order to help combat air pollution and nuisance and to monitor long-term trends and improvements resulting from national and Community measures
- ensuring that such information on ambient air quality is made available to the public
- maintaining air quality where it is good and improving it in other cases
- promoting increased cooperation between the Member States in reducing air pollution.

The CAFE Directive states:

> a common approach to the assessment of ambient air quality should be followed according to common assessment criteria. When assessing ambient air quality, account should be taken of the size of populations and ecosystems exposed to air pollution. It is therefore appropriate to classify the territory of each Member State into zones or agglomerations reflecting the population density.

and

> in order to ensure that the information collected on air pollution is sufficiently representative and comparable across the Community, it is important that standardised measurement techniques and common criteria for the number and location of measuring stations are used for the assessment of ambient air quality. Techniques other than measurements can be used to assess ambient air quality and it is therefore necessary to define criteria for the use and required accuracy of such techniques.

In regard to methods, clause 24 states

> it is appropriate to provide for the possibility of adapting the criteria and techniques used for the assessment of the ambient air quality to scientific and technical progress and adapting them to the information to be provided.

3.2.1 Population criteria

The EU Directive requires that member states establish zones and agglomerations throughout their territory as the basis for air quality assessment. Zones are defined by member states and agglomerations are defined as: 'a zone that is a conurbation with a population in excess of 250,000 inhabitants or, where the population is 250,000 inhabitants or less, with a given population density per km².'

There are also specific requirements that cover sulfur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide, with separate requirements for ozone.

Essentially these directives and definitions set a minimum requirement for a monitoring station ('sampling point') as one per 250,000 people.

3.2.2 Spatial scales

The population requirements are supplemented by further directives that require that zones and agglomerations supplement monitoring information with information from modelling and/or indicative measurements. This allows the total number of fixed sampling points to be reduced by up to 50%, provided:

- the supplementary methods provide sufficient information for the assessment of air quality with regard to limit values or alert thresholds, as well as adequate information for the public
- the number of sampling points to be installed and the spatial resolution of other techniques are sufficient for the concentration of the relevant pollutant to be established in accordance with the data quality objectives specified in Section A of Annex I and enable assessment results to meet the criteria specified in Section B of Annex I.

Due to the large potential for transport of pollutants, the spatial extent of $PM_{2.5}$ monitoring is defined differently, and the EU requires one sampling point for every 100,000 km² (Table 4).

3.2.3 Screening criteria

The EU also uses a concept of estimated or measured air pollution thresholds to assist with network design and allow reduced monitoring. This is a similar approach to the screening criteria used in the NEPM. In the EU, where fixed measurements are the sole determination of air quality conditions, the 'upper assessment threshold' (UAT) and the 'lower assessment threshold' (LAT) are used to guide network design.

Conceptually, the prevailing ambient air quality concentrations define the broad requirement for monitoring within the EU Air Quality Directives (Figure 1).

3.2.4 Review

The upper and lower assessment thresholds are used as the primary tool for determining network design and review. Where data supports the redesignation of an agglomeration to a different category as achieving the UAT or LAT, the requirements of that category would apply. Compliance is determined annually, and adjustments to monitoring may be required based on the assessment of compliance over the previous five years, or when fewer than five years' data are available through campaign (short-term) monitoring and information from emission inventories and modelling.

Table 4 Spatial scales for the designation of station types (EU)

Station type	Spatial scale	Objectives	Macroscale siting criteria
Urban	A few km²	Protection of human health	Away from the influence of local emissions such as traffic, petrol stations, etc.
		To assess the exposure of the urban population to ozone, i.e. where population density and ozone concentration are relatively high and represent the exposure of the general population	Vented locations where well mixed levels can be measured
Suburban	Tens of km²	Protection of human health and vegetation	At a certain distance from the area of maximum emissions, downwind following the main wind direction/directions during conditions favourable to ozone formation
		To assess the exposure of the population and vegetation located in the outskirts of the agglomeration, where the highest ozone levels, to which the population and vegetation are likely to be directly or indirectly exposed occur	Where population, sensitive crops or natural ecosystems located in the outer fringe of an agglomeration are exposed to high ozone levels
			Where appropriate, some suburban stations also upwind of the area of maximum emissions, in order to determine the regional background levels of ozone
Rural	Sub-regional levels (100s of km²)	Protection of human health and vegetation	Stations can be located in small settlements and/or areas with natural ecosystems, forests or crops
		To assess the exposure of population, crops and natural ecosystems to sub-regional-scale ozone	Representative for ozone away from the influence of immediate local emissions such as industrial installations and roads
			At open area sites, but not on summits of higher mountains
Rural background	Regional/ national/ continental (1,000 to 10,000 km²)	Protection of vegetation and human health	Station located in areas with lower population density, e.g. with natural ecosystems, forests, at least 20 km from urban and industrial areas and away from local emissions
		To assess the exposure of crops and natural ecosystems to regional-scale ozone	Avoid locations which are subject to locally enhanced formation of ground-near inversion conditions, also summits of higher mountains

	concentrations as well as exposure of the population	Coastal sites with pronounced diurnal wind cycles of local character are not recommended

<table>
<tr><th></th><th>Compliance</th><th>Assessment</th><th>Requirements</th></tr>
<tr><td>Limit value</td><td>Non-compliance</td><td rowspan="3">Regime 1</td><td rowspan="3">High quality measurement is mandatory. Data from measurement may be supplemented by information from other sources, including air quality modelling</td></tr>
<tr><td>UAT
(upper assessment threshold)</td><td rowspan="3">Compliance</td></tr>
<tr><td rowspan="2">LAT
(lower assessment threshold)</td></tr>
<tr><td>Regime 2</td><td>Measurement is mandatory, but fewer measurements may be needed, or less intensive methods may be used, provided that measurement data are supplemented by reliable information from other sources</td></tr>
<tr><td></td><td>Regime 3</td><td>In agglomerations, only for pollutants for which an alert threshold has been set

Modelling, objective estimation, and indicative measurements alone are sufficient</td></tr>
</table>

Figure 1 Conceptualised requirements for monitoring – 2008/50/EC

3.3 Canada

In Canada, a number of pollutants are managed through Canada-wide Standards (CWS) under the Canadian Council of Ministers of the Environment (CCME) Environmental Standards Sub-Agreement. CWS are applied at federal, provincial and territorial levels of government across Canada to address environmental and health risk matters.

Under the CWS for particulate matter and ozone, each jurisdiction was afforded significant freedom and flexibility in the design of the implementation plan. This was critical given the variability of environmental conditions across Canada; for example, some jurisdictions which are geographically proximate to the international border with the United States considered transboundary air pollution to be a major component to manage, whereas other jurisdictions faced challenges in managing background concentrations from naturally occurring events (such as forest fires) and diffuse local emissions (such as wood burning for household heat).

In 2010 the CCME agreed to strengthen the CWS for particulate matter and ozone by implementing the collaborative Air Quality Management System (AQMS) (CCME 2011). The AQMS contains several key elements, including: development of new Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$ and ozone; more formalised delineation of air zones and airsheds; and an Air Zone Management Framework.

Under the AQMS, provinces and territories were delineated into 'air zones'. Each air zone is defined to be reflective of general air quality within its boundary and broadly typifying similar local source contributions and circumstances.

Canada is further delineated into regional airsheds (each comprising one or more air zones), which serve as the basis for coordinating action between jurisdictions on transboundary/ inter-jurisdictional air quality issues. Each province and territory is required to establish CAAQS reporting stations for each air zone. The purpose of the CAAQS reporting stations is to provide achievement status against the CAAQS in each air zone, and network design is guided by population and spatial considerations.

3.3.1 Population criteria

The minimum requirement is for one CAAQS reporting station for a population of 100,000 inhabitants, although the AQMS does allow jurisdictions to locate stations reflective of populations below this threshold in smaller rural communities or if there is significant spatial variability.

In defining community size, Canada uses definitions of geographic units provided by Statistics Canada, which may be used to group municipalities that are closely interconnected (geographically or economically) and/or may be reasonably aggregated as air zones.

The *Guidance Document on Achievement Determination: Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* (CCME 2012a) provides 'reference' populations from Statistics Canada based on Census Metropolitan Area (CMAs – population >100,000) and Census Agglomerations (CAs) which are lower than the threshold based upon 2006 census data. The Canadian Council of Ministers of the Environment (CCME 2012a) lists that the population captured by CMAs and designated CAs accounts for >81% of the Canadian population.

3.3.2 Spatial scales

Each province and territory is required to establish CAAQS reporting stations for each air zone. These stations are required to account for spatial variability in $PM_{2.5}$ and ozone concentrations. Where there is enough evidence that a single reporting station is justified in providing representative $PM_{2.5}$ and ozone data for the air zone, a single station may be permitted. Otherwise, the jurisdiction must provide evidence to the federal government that defines the number of stations required to adequately describe the variability.

A reporting station located in a regional/rural location is required to be representative of a 'regional' scale, whereas siting in a community location is required to be representative of a 'neighbourhood' or 'urban' scale (as defined by the US EPA (US EPA 1998)) and not overly biased by local emissions from industry or transport. In terms of CAAQS reporting stations for ozone, they should be in a location representative of the expected maximum ozone concentrations, which is naturally located outside of the urbanised areas.

3.3.3 Review

The CCME *Guidance Document on Air Zone Management* (CCME 2012b) sets out the Air Zone Management Framework (AZMF) and provides guidance on the implementation of air quality management to achieve and maintain the CAAQS under the AQMS.

4. Discussion and recommendations

4.1 Monitoring plans

The Peer Review Committee guidance covers a broad range of issues associated with the implementation of the NEPM and is comprehensive and more comprehensible and easier to access than many other guidance documents (e.g. US EPA, EU Directives).

The Peer Review Committee guidance documents cover issues associated with:

- the structure of monitoring plans
- selection of regions
- monitoring strategies
- screening procedures
- data collection and handling
- meteorological measurements
- annual reporting.

They provide a basis for consistency in approaches across all Australian jurisdictions.

Each jurisdiction provided an NEPM monitoring plan in 2001 for review by the National Environment Protection Council (with South Australia performing a review of the monitoring plan in 2005). All these plans (except SA) are 15 years old and do not reflect the current monitoring being performed for NEPM compliance purposes in any jurisdiction.

The current networks operated in each jurisdiction differ from those proposed in the monitoring plans as the networks have evolved over time based on changes in population, the requirements of the NEPM, and on the results of campaign monitoring and application of screening procedures. However, there is a lack of transparency and consistency in how these changes in monitoring networks are communicated.

It is recommended that the NEPM monitoring plans for all jurisdictions be updated. It is further recommended that a defined frequency for provision of updated monitoring plans is agreed upon to ensure the plans consider changes in population coverage, monitoring methods and other changes effected through the NEPM. For comparison, the United States Environmental Protection Agency requires provision of monitoring plans on an annual basis.

Recommendation 1 – Jurisdictional monitoring plans should be updated annually with changes documented clearly and transparently.

Recommendation 2 – Jurisdictional monitoring plans should be reviewed and re-submitted every five years to ensure currency of population coverage and pollutant screening assumptions.

4.2 Population thresholds

The NEPM is flexible in respect to air quality monitoring, and jurisdictions are able to implement monitoring in any location, and are not restricted to the 25,000 population threshold.

The review of international best practice for the design of monitoring networks found that all major networks comparable to the NEPM use population as the primary basis for establishing minimum monitoring (or assessment) criteria. Further, the NEPM population threshold of 25,000 is stricter than all other population-based approaches. Typically, in the USA, Canada and the EU population thresholds start at 100,000 people and range from 100,000–1,000,000.

Recommendation 3 – The population threshold of 25,000 to guide monitoring network design and NEPM assessments should be retained.

Populations have increased (often significantly) between the submission of the 2001 monitoring plans (which were based on 1996 census data), and the most recent 2011 census. The Australian Bureau of Statistics now provides more comprehensive census population products. The Urban Centres and Localities (UCL) product was used in the Peer Review Committee guidance to provide the required information on populations in urban centres for the purposes of the NEPM; however, the ABS now provides a Significant Urban Area (SUA) product which takes into account the contiguous nature of urban development. Should the population threshold of 25,000 remain within the NEPM, the benefits of using the SUA product as opposed to the UCL product should be investigated.

Recommendation 4 – The Australian Bureau of Statistics Significant Urban Area (SUA) product should be the basis of population assessments for monitoring design.

4.3 Spatial scales

There is a significant amount of inconsistency between monitoring plans and annual reports in the designation of monitoring station ‘types’. The NEPM requires the designation of performance monitoring stations and trend stations, although the PRC technical papers also discuss the designation of population-average and generally representative upper bound (GRUB) stations. The application of these concepts and nomenclatures is not consistent between jurisdictions, indicating a level of uncertainty as to their purpose.

4.4 Pollutant screening

The NEPM allows for fewer monitoring stations where it can be demonstrated that pollutant levels are reasonably expected to be consistently lower than the standards. The PRC outlined a range of screening procedures that can be used to demonstrate this expectancy in a transparent manner, including: monitoring; modelling; a combination of monitoring/ modelling; comparison with other similar regions; and non-standard monitoring methods.

This screening approach is much like the EU, USA and Canada approaches. For example, the lower and upper assessment thresholds (LAT and UAT) are not only used to assess compliance with the EU Directives, but also to justify monitoring requirements. In Canada, the Air Management Threshold Values of the Air Zone Management Framework set different monitoring requirements based on the different management levels. In the USA, the EPA allows jurisdictions to monitor at fewer locations for particles (and ozone) based on a combination of population and concentrations that are <85% (<80% for ozone) of the NAAQS.

The screening procedures were originally published in November 2000 and formed the basis of the monitoring plans submitted by each jurisdiction in 2001. They were revised in 2007 to incorporate updated modelling results of NO_2 and ozone concentrations expected in regional centres and coastal cities. The NEPM does not specify the need for periodic review of screening; however, PRC Technical Paper No. 4 recommended that jurisdictions formally review screening determinations at five-yearly intervals (or sooner if there are indications of a significant upward trend in emissions or concentrations) (PRC 2007).

Recommendation 5 – Jurisdictions should re-assess their screening determinations at the earliest time practicable.

The application of screening procedures was performed by each jurisdiction in the 2001 monitoring plans. Screening procedures were updated in 2007 and many jurisdictions have not revisited the application of these procedures, especially regarding ozone monitoring. Based on findings of the CSIRO TAPM consultancy (findings which were incorporated into the screening procedures in 2007), it is likely that ozone monitoring may be required in a number of inland centres that meet the population screening criterion of 25,000.

Recommendation 6 – Jurisdictions should re-assess ozone monitoring requirements based on the updated 2007 screening procedures, focusing on large inland and coastal centres.

Current screening procedures do not reflect changes to the NEPM; for example, PM_{10} screening still refers to the fifth highest value. Similarly, there is no screening procedure for $PM_{2.5}$.

Recommendation 7 – Screening procedures for $PM_{2.5}$ should be developed and screening procedures for PM_{10} should be updated to reflect changes in the NEPM, focusing on maximum PM_{10} levels excluding exceptional events.

Monitoring plans should be consistent. Additional guidance in the designation of stations is recommended and it is also recommended that application of screening procedures should be provided either by the Peer Review Committee, or another agreed expert group.

Recommendation 8 – An expert group should review trends in monitoring network design and advise jurisdictions on changes to monitoring design requirements. The group may also act as a review panel for monitoring plans.

The designation of performance monitoring stations and minimum requirements can be clarified by reordering the wording of clause 14 and demonstrating that population exposure and risk characterisation is the primary goal of monitoring network design.

Recommendation 9 – Clause 14 of the NEPM should be amended to:

14 Number of performance monitoring stations

(1) The number of performance monitoring stations in a region should be based on a determination of the potential pollutant exposure risk to the region's population.

(2) Additional performance stations may be required to determine population exposure in high risk areas.

(3) Subject to subclauses (1) and (2), the minimum number of performance monitoring stations for a region with a population of 25,000 people or more must be the next whole number above the number calculated in accordance with the formula:

$1.5P + 0.5$

where ***P*** is the population of the region (in millions).

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Attachment A: EWG Project 2 work plan

Principles

The project team agreed that principles guiding monitoring network design be adopted to frame the group's work. It was agreed that monitoring networks should:

- support efficient use of resources
- provide adequate spatial and population coverage
- adhere to consistent design principles
- allow flexibility in design
- retain and build upon the value inherent in long-term trend monitoring stations.

Scope of work

The project team agreed that the following aspects were out of scope:

- Modelling, including land-use regression modelling, and approaches to blend modelling and monitoring. This was deemed to be within the scope of Project 3.
- Selection of specific monitoring techniques and provision of guidance on collocation studies for instruments. This was deemed to be within the scope of Project 1.
- Crowdsourced, community-based monitoring.
- Pollutants other than current Ambient Air Quality NEPM pollutants and $PM_{2.5}$.

Proposed timelines

Task	Deliverable	Leader	Due date
Project team to agree on project principles, scope of work, project plan	Endorsed principles & work plan	NSW OEH	18/09/2015
Review existing Australian/State/Territory/AS guidance on monitoring networks and monitoring station design and their current implementation	Review report	NSW OEH	30/11/2015
Review international best practice for monitoring network design, focusing on compliance monitoring, trend monitoring, and tier-2 networks	Review report	NSW OEH	31/12/2015
Support Project 3 to review international guidance on monitoring network design for exposure assessment	Support for Project 3	NSW OEH	Align with Project 3 timelines
Compile review findings and draft guidance/ recommendations on monitoring network design	Discussion paper	NSW OEH	28/02/2016

Attachment B: NEPM review – monitoring

Clauses 10–16 of the NEPM set out methods and procedures related to monitoring air pollution. They include clauses related to the preparation of jurisdictional monitoring plans; measurement and monitoring methods, including the location, number and type of monitoring stations; and accreditation, quality assurance and validation procedures.

Comments from stakeholders focused on the adequacy of current monitoring networks, particularly the number and location of monitoring stations, and how representative the networks are of exposure of the population. There were also several comments on the Australian standard measurement methods.

Location and number of performance monitoring stations

NEPM subclauses 13(1) and 13(2) provide guidance on the location of performance monitoring stations, in accordance with the Australian Standard AS 2922-1987: Ambient air – guide for siting of sampling units. Stations must be located to contribute to obtaining a representative measure of the air quality likely to be experienced by the region's general population.

The PRC developed the concept of GRUB stations as an additional category to those cited in AS 2922-1987. The intent was to provide some sense of population exposure by focusing on the higher levels to which a regional population was likely to be exposed, without direct influence of local sources such as major traffic areas; i.e. where large portions of the population experience similar average air quality. The effectiveness of this new category was predicated on preliminary work to ascertain the representativeness of chosen sites. In some instances, this was based on good background information from monitoring or modelling programs, so the term was well justified. In areas where resources were limited, and particularly where single stations were installed to represent large urban areas, it was not always clear that such sites were chosen based on rigorous science, so their 'representativeness' of upper bound exposure may not have been well established. The question for several commentators was whether the GRUB concept adds any value to understanding impacts of air quality.

Strong representations were made by several commentators that, while the GRUB concept was useful as an initial approach, a broader mix of station types would better reflect the exposure of the population. Health sector and community organisations advocated a mix of industrial, major roads, low impact suburban, etc., to provide a picture of potential exposure to air pollutants. This is not to say that current GRUB stations should necessarily be deleted; more, that they should continue to inform trends but as part of a wider approach to population monitoring that seeks to understand patterns of pollution and exposure.

Some commentators pointed to the lack of clear definitions surrounding the GRUB concept as described in the PRC's *Technical paper no. 3: Monitoring strategy* (PRC 2001c). Examples include '…a substantial area and fraction of the population', and '…large portions of the populated area'. The commentators saw these terms as being open to fairly broad interpretation. Some industry comment also did not support the use of GRUB sites and recommended removal of the term.

A significant industry group put forward the view that there are several problems with GRUB sites including that:

- their application appears incongruous with existing NEPM monitoring station definitions
- there is lack of scientific and stakeholder consensus as to the application of GRUB sites
- the use of GRUB sites will not yield data that are representative of the average population exposure or trends in overall ambient air quality.

Industry favours the approach taken internationally to determine population exposure; however, it cautions against the implementation of this approach without due consideration to providing adequate direction and guidance towards nationally consistent application.

Internationally, there has been a move to establish air monitoring networks to allow population exposure to be determined; for example, the EU, the US EPA (US EPA 2005b), and the WHO (WHO 2000). The air monitoring networks are based on consideration of population density, sources, distribution of pollutants within an airshed, and the concentration of a pollutant relative to air quality standards. A range of sites is recommended, including background (urban and rural), peak, rural, urban and suburban. Air quality modelling is a tool that is used to assist in the siting of air monitoring stations to ensure an appropriate mix of stations enables population exposure to be determined.

Comment received on behalf of the PRC itself advocates retention of GRUB stations and disagrees with the concept of the NEPM providing information on population exposure beyond evaluating compliance with standards at these sites of 'upper bound' exposure.

The population formula in subclause 14(1) of the NEPM provides guidance for jurisdictions to determine the number of performance monitoring stations within a given region. The formula embodies a lower population limit of 25,000, below which no monitoring is required; however, the formula is qualified in subclauses 14(2) and 14(3) to allow for more or fewer stations according to specific regional or local characteristics.

A considerable number of commentators focused on the population threshold of 25,000. Respondents generally considered this limit to be an impediment to effective monitoring and therefore to adequate protection of populations, particularly those in small regional centres that characterise populations in several jurisdictions. One commentator pointed to specific issues in small mining towns where pollution levels are high. The population formula was seen by some as a product of 'compliance mentality' in conflict with the NEPM's original intent and international trends towards population exposure monitoring.

Most of the issues with jurisdictional monitoring programs were seen to be more the result of resource issues than concepts embodied in the formula. One commentator suggested that some jurisdictions interpreted guidance from the PRC in a way that allowed them to establish fewer stations than would have been required under clause 14 of the NEPM.

Comment from the PRC was that the population formula does not limit the number of stations, based on the wording of clause 14 which allows for additional or fewer stations according to specific needs and circumstances. However, as noted above, other commentators suggested that in practice, jurisdictions generally interpreted clause 14 to limit the number of stations.

Review findings — location and number of monitoring stations

The Review Team concluded that the GRUB concept does not fit well with current population exposure approaches, and the station categories cited within AS 2922-1987 provide enough capacity to monitor the range of air environments required. The GRUB concept is not part of the NEPM. There has been confusion around some of the terms used to define GRUB stations and the factors used for their establishment, and this has led to inconsistencies between jurisdictions. For these reasons, the Review Team considers that the use of the GRUB concept should be discontinued, and that careful consideration should be given to the optimal range and configuration of station types to provide a coherent picture of population exposure for the selected indicators for each population centre.

The Review Team also considers that the population formula and threshold should be removed and a more risk-based approach to monitoring be adopted across regional populations rather than population centres. The population formula is seen as an impediment to effective monitoring and therefore to adequate protection of populations, particularly those in small regional centres that characterise populations in several jurisdictions.