FINAL REPORT

Establishing a Visibility Goal for Wilderness and Urban areas in British Columbia and Canada

CONSULTING ENGINEERS & SCIENTISTS

Project Number: #W08-1088

March 31, 2008

SUBMITTED TO:

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March 31, 2008

B.C. Ministry of Environment
2975 Jutland Road
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Attn: Mr. Steve Sakiyama

Dear Steve,

RWDI AIR Inc., in collaboration with Sonoma Technology Inc. and Dr. Douw Steyn, is pleased to submit this report on Establishing a Visibility Goal for Wilderness and Urban areas in British Columbia and Canada. This report provides a framework for protecting visibility that includes several key steps: initiating the process, setting or reassessing a visibility goal, developing science and social science programs, implementing the program, and analysing data and tracking progress.

It has been a pleasure working with you and the rest of the Coordinating Committee on this project.

Sincerely,

RWDI AIR Inc.

Kelvin Campbell

Kelvin Campbell, P. Eng.
Project Manager / Senior Specialist

Cc: June Yoo Rifkin, Environment Canada
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1.0 INTRODUCTION

Air quality and good visibility are highly valued in British Columbia (B.C.). In February 2005, Premier Gordon Campbell declared in the Speech from the Throne that one of the five Great Goals for a Golden Decade in B.C. was "To lead the world in sustainable environmental management, with ***the best air*** and water ***quality***, and the best fisheries management, ***bar none***." (Speech from the Throne 2005) Improving visibility is one of three goals of Metro Vancouver's 2005 Air Quality Management Plan (AQMP). The Fraser Valley Regional District's (FVRD) AQMP also has four recommendations specifically related to inhalable particulates and visibility. Furthermore, the definition of "air contaminant" in the B.C. Environmental Management Act includes substances that interfere with or are capable of interfering with visibility. Despite this, there are currently no specific visibility objectives or goals in B.C. or the rest of Canada.

Visibility impairment can affect quality of life and has been shown to have an indirect economic impact. But more importantly, visibility impairment is linked to the fine particles that are of considerable public health concern. In the Lower Fraser Valley (LFV) visibility can be impaired at ambient particulate pollution levels less than the Metro Vancouver objective for fine particulate ($PM_{2.5}$)[1]. Thus, one can anticipate that a visibility objective for the LFV would constitute an environmental quality criterion more stringent than that of the current ambient air quality criteria based on protection of human health. Since population-level thresholds for adverse effects have not been shown to exist for particulate pollution (Bates et al. 2003) any improvement in air quality for particulate matter would result in fewer negative health impacts. Thus, there is a strong argument to be made that by improving visibility there will be a co-benefit of reducing particulate matter health impacts.

In December 2007, the B.C. Ministry of Environment (MOE) issued an Invitation to Quote (ITQ) entitled "A Visibility Goal: Exploring Options". RWDI AIR Inc., in partnership with Sonoma Technology Inc. and Dr. Douw Steyn, was awarded the contract in response to the ITQ. This report summarizes the results of our study.

[1] For example, in 2006, the Metro-Vancouver 24-hour $PM_{2.5}$ objective of 25 µg/m^3 was exceeded in the FVRD for only two days in early September in both Chilliwack and Hope due to forest fire smoke (Metro Vancouver 2007). Visibility was impaired in the FVRD on more than two days in 2006. Also, $PM_{2.5}$ levels observed during visibility episodes depicted in Jacques Whitford Axys (2007) are 15 µg/m^3 or less.

The objective of this study is to establish a science and policy foundation to serve to develop visibility goals for urban and wilderness areas. The desired outcome of the project is a process for establishing a draft visibility goal for the Lower Fraser Valley that will ultimately be the cornerstone to a visibility protection pilot program for the valley. Optimally, the goal and the process will have generic elements to allow for its broader application to B.C. and the rest of Canada.

This study involved a literature search and interviews of United States (US) agencies that have been involved with visibility management in the US. The literature search was fairly limited in scope and consisted of examining a few comprehensive reviews of factors affecting visibility, methods to monitor visibility and ways to manage visibility. Rather than repeating this information, this document builds on previous work to outline a recommended process for developing, managing, and implementing a program to maintain and improve visibility in both urban and wilderness areas of B.C. and the rest of Canada.

1.1 RECENT INITIATIVES TO ADDRESS VISIBILITY IN B.C.

Visibility has been an issue in the Lower Fraser Valley for many years, but has mainly been addressed through efforts to reduce air pollution levels in general and certain smog-forming pollutants in particular.

The most notable exception to this is the study titled Regional Visibility Experimental Assessment in the Lower Fraser Valley (REVEAL). This field study was designed to provide a first analysis of visibility degrading aerosols in the LFV (Pryor and Steyn, 1994 a, b & c). Subsequent analyses of the REVEAL data (Pryor et al, 1994) performed source apportionment analyses of visibility degrading aerosols in the Lower Fraser Valley, and public perception surveys using the photographs and optical measurements taken during REVEAL (Pryor, 1996) devised and tested in a protocol for gauging public perception of visibility in this region.

In addition, Metro Vancouver currently operates a nephelometer and a network of six automated digital cameras to record views along specific lines of sight with recognizable topographical features at known distances in the LFV. Also, a recent national visibility assessment was undertaken that includes sites in B.C.

The most recent initiative to address visibility began in October 2006 with a meeting of the B.C. Visibility Coordinating Committee (BCVCC), which consists of representatives from the MOE, Environment Canada, Metro Vancouver and the FVRD. This resulted in the preparation of the report entitled "The View Ahead: Identifying Options for a Visibility Management Framework for British Columbia" (Jacques Whitford AXYS, 2007).

The View Ahead identified five management options for BCVCC to consider: i) status quo – no new efforts for visibility protection; ii) include visibility considerations in the implementation of Canada-wide Standards; iii) leverage existing policy directives and establish visibility as a protected value; iv) visibility protection by establishing visually important areas in B.C. through legislation; and v) develop a national visibility management program. The current study is most closely related to the third option as it involves setting visibility goals and establishing programs that are implemented using existing air quality management mechanisms.

The BCVCC held a workshop with stakeholders from various sectors on June 19th, 2007 primarily to discuss the five options presented in The View Ahead, but also to discuss the importance of visibility to sector stakeholders (BCVCC 2007). This report is, in part, a response to the last three of the following key workshop themes:

- visibility is an important way in which the public perceives air quality and enjoys the environment;
- air quality management efforts that target common air contaminants and greenhouse gases may also improve visibility – it is important to build upon existing efforts in air quality management to match efforts as well as capitalize on current momentum;
- there are significant data gaps in understanding current levels of visibility: science, monitoring and assessment are important components in all of the management options;
- other than the status quo option, there will be a need to define visibility goals, standards and target areas; and
- other stakeholders need to be consulted, including First Nations, parks sector and other business interests.

Subsequent meetings and outreach over the summer and fall of 2007 culminated in a meeting on November 9th, 2007 at which a path forward was determined and a draft work plan was developed. A schematic of the draft work plan is shown in Figure 1-1.

The plan includes three concurrent activities, shown at the top of Figure 1-1, with the centre one being this study. The other two are the development of a draft five-year vision for visibility management in Canada, and a study on lessons learned from the US experience with visibility issues. The next step was a workshop to report on the conclusions of these three activities, which took place on March 26-27, 2008.

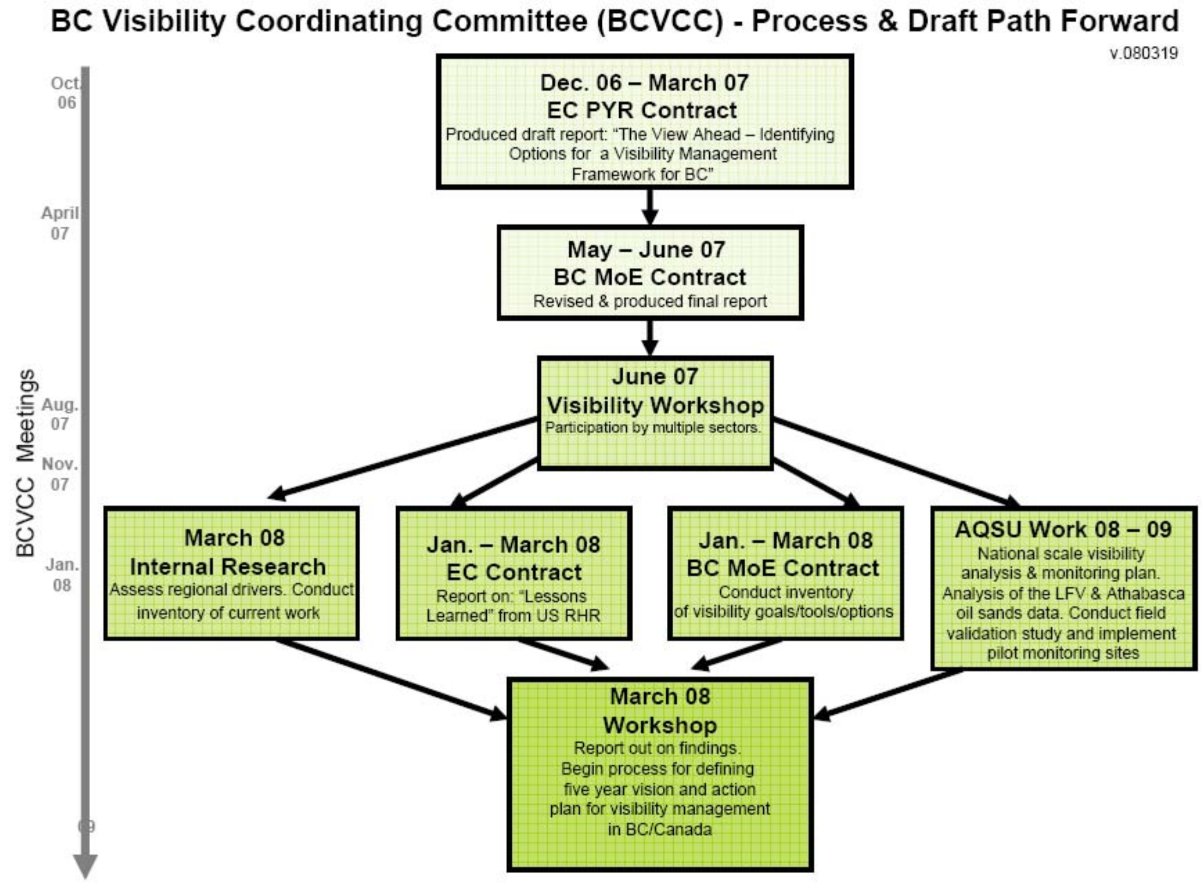

Figure 1-1: B.C. Visibility Coordinating Committee Draft Work Plan

Over the next year, the draft work plan calls for establishment of a visibility goal for the Lower Fraser Valley Transboundary airshed and ultimately a pilot project implementing that visibility goal.

1.2 REPORT LAYOUT

The proposed framework for protecting visibility is introduced in Section 2. The framework is cyclical and the four steps in the cycle are discussed in greater depth in Sections 3 to 6. Our recommendations are summarized in Section 7. Results of interviews with US agencies are provided in Appendix A.

2.0 FRAMEWORK FOR PROTECTING VISIBILITY

Figure 2-1 shows a conceptual framework for protecting visibility that could be applied to the Lower Fraser Valley and to the rest of B.C.. The framework should be a cyclical process. After initiating the process, the first time through the cycle consists of analysing data to help set goals; setting visibility goals (including determining the form and metrics of the goals); developing science and social science programs to advance our understanding of visibility issues; and implementing a visibility management program. Data will then be analyzed to track progress in achieving the visibility goals. At this point, the cycle begins again with a reassessment of the goals. The science and social programs are then adjusted and the visibility management program is updated, if required. As the program matures, each step can be revisited to adjust to new findings and environmental conditions. Each step may begin with or include public outreach and stakeholder participation.

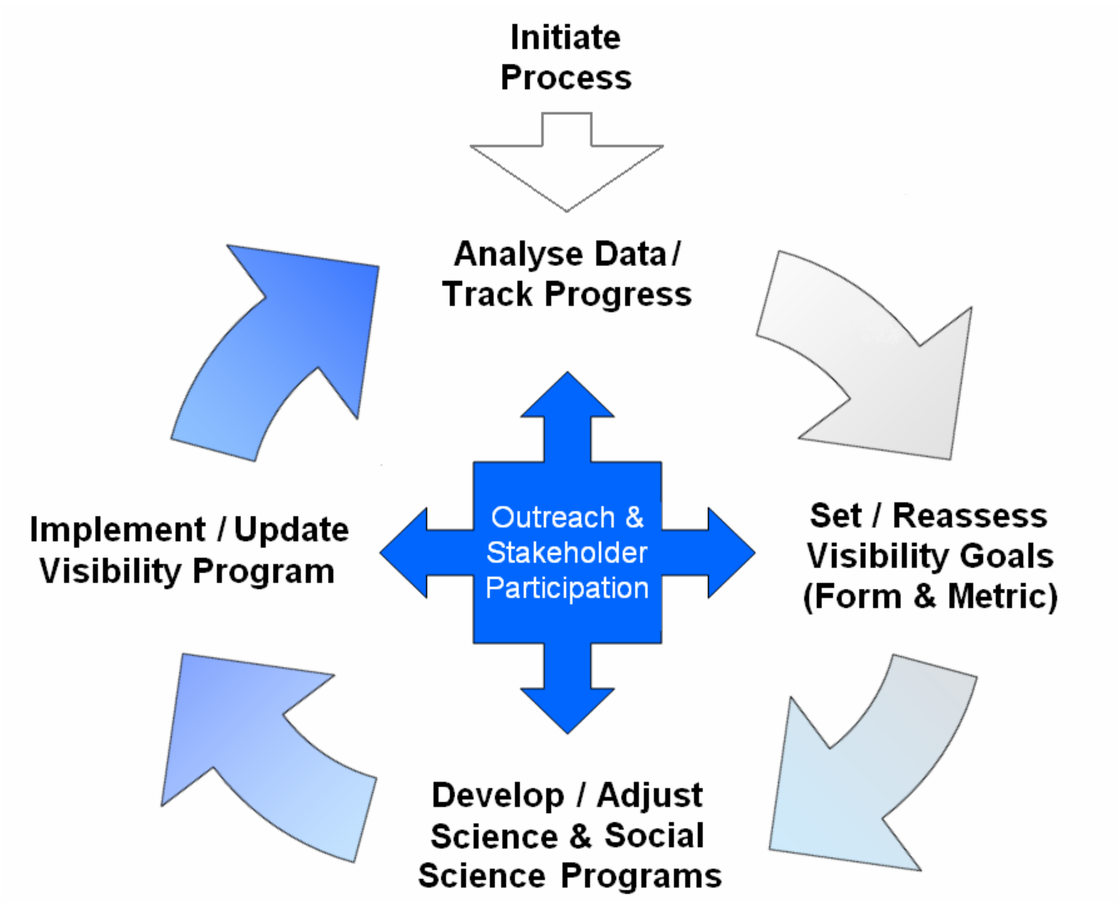

Figure 2-1: Conceptual framework outlining steps for visibility protection. The recommended period is two years for the first cycle and every five years after that.

3.0 SETTING A VISIBILITY GOAL

3.1 INITIATING THE PROCESS

The BCVCC has already initiated the process of setting a visibility goal through sponsorship of contractor projects in early 2008 including this project and an investigation of lessons learned from the US experience with the Regional Haze Rule. Recommendations from this work can be used to take the next steps in setting and implementing a visibility goal.

3.2 SETTING AN INITIAL VISIBILITY GOAL

Setting a visibility goal or policy provides a target for the visibility process to move forward. With a visibility goal, visibility measures will be included in air quality management plans, visibility measurements will be implemented, and trends can be tracked. Based on advice received from US agencies during interviews, key considerations in setting a goal include the following:

- A collaborative approach to goal setting using workshops and consultation with important stakeholders, rather than taking a top-down approach like the US Clean Air Act (CAA). Some questions that need to be addressed include: Is public debate needed as to what a visibility goal should be? Do some special areas need to be protected? Does protection mean bringing visibility to natural background levels? Should a threshold be established that says "yes, we'll accept some impairment" or should a threshold be adopted that is "not to be exceeded"?
- A format that can be applied to a range of situations from wilderness areas to urban areas is more desirable than separate standards.
- A review of the emission inventory before setting goals will aid in determining which parts of the inventory are potentially controllable. This approach will help base the goals on a realistic analysis of the relative contributions to visibility over which air quality officials have control. Consider how emissions change over time and changes that may result because of increased goods movement, climate change, and natural resource extraction.
- Choosing a milestone and implementation period that has the potential for success will make longer term goals feel more attainable.

- During the goal-setting process, there may be a need to understand and potentially quantify visibility degradation in the specific area of concern, such as the LFV.
- On reading the available literature and speaking with visibility experts, it became clear to the team that visibility considerations need to include three rather than two classifications: urban, rural, and wilderness (see text box Urban, Rural and Wilderness).

Urban, Rural and Wilderness

There is no formally accepted definition of the terms *urban, rural and wilderness*: Usually urban and rural make up a contrasting pair. The most important distinction between all three lies in population density (and in the present context, emissions density) but there are no firmly established limits. In very rough terms, rural implies a population density between 10 and 100 people per square km. Urban and wilderness are above and below. Also important is the extent (total population or total emissions) of each and the homogeneity (or lack thereof) of emissions and thus air parcels impacting the population. These three terms are thus undefined but reasonably well understood.

- While all three area classifications occur in the LFV, it must be recognized that the LFV comprises a remarkably diverse "visibility region". There are many sight lines which originate in dense urban areas, traverse rural areas and terminate on vistas that are completely undeveloped wilderness. Most notable (and extreme) of these are the lines originating in the extraordinarily dense (by any standard) West End of the City of Vancouver and terminate on the spectacular vistas of Mount Baker, passing over: suburban Vancouver, Burnaby and New Westminster; rural communities of Langley and Aldergrove; and the agricultural land that lies between them. Conversely, there are sightlines from farmland in the centre of the LFV which pass over the downtown core of Vancouver and terminate on the snow-capped North Shore Mountains. Many of these sight lines are no longer than 50 km, and thus comprise a visibility resource that should be accessible with no more than modest visibility degradation. It is thus clear that visibility protection in the LFV presents some particularly difficult questions. Whichever way the matter is considered, a wilderness goal is needed to protect wilderness vistas, and if an urban area is within visible range of wilderness vistas on clear days, then a wilderness goal should prevail over both urban and wilderness areas. This is in fact implicit in the work of Pryor (1994, 1996) and also that of McNeill and Roberge (2000, 2007). All of the scenes used in these public perception surveys were of wilderness vistas. It is also important to realize that the same index will be used for urban, rural and wilderness areas, but the goal (expressed as critical values of the index) will be different.

- Thinking about visibility protection for all three classifications as they co-exist in the LFV will make a visibility management program, such as one developed for LFV, more readily adaptable to the rest of B.C. or Canada.
- Three goals, or a combination of these goals, are the most likely candidates for improving or protecting visibility:
  - Limit the number of poor visibility days (e.g., Denver's visibility threshold, or the Regional Haze Rule's bottom 20% component)
  - Increase or maintain the number of excellent visibility days (e.g., Phoenix's goal to improve excellent visibility days, or the Regional Haze Rule's cleanest 20% component)
  - Improve visibility on all days (e.g., Phoenix's goal to shift the distribution from poor visibility days to good and excellent visibility days).

To ensure that visibility goals are enforceable, thought will need to be given to establishing methods that would lead to policy changes and emission controls if progress towards better visibility is not made.

3.3 FORM AND METRIC OF THE GOAL

An approach that provides flexibility to cover urban to wilderness areas is to adopt a visibility index. A visibility index could be developed to include both a quantitative measure of visibility and public perception. Such an index could be set up akin to the Air Quality Health Index (AQHI), with categories binning visibility conditions among a number of categories (e.g., poor, moderate, very good, and excellent). The index could be colour- and word-coded similar to the AQHI. The categories could be used for public outreach similar to AQHI, asking for action on days of poor visibility due to manmade causes. The science behind the index could be complex (e.g., expressing visibility impairment in terms of inverse megameters or deciviews (see text box).

It is most important to recognize that there will be instances when the AQHI and visibility index disagree in the sense that the visibility index may indicate that a goal is not reached, while the AQHI indicates its applicable goals are reached. Protecting health and protecting visibility are not the same thing. This is a reality that all sectors of society will have to be prepared for. At the moment there is a disconnect because the public perceive visibility as degraded, but receive an AQI that indicates no degradation of air quality. Formalizing both AQHI and Visibility Index (VI) that have similar (if not identical) structure, but can have different values will provide a tool for education of all sectors of society. The goal will be to understand that AQHI and VI reflect different deleterious effects of air pollution.

Definitions

Inverse megameter (Mm^{-1}) is the direct measurement unit for visibility impairment data. It is the amount of light scattered and absorbed as it travels over a distance of one million meters.

The **deciview** is a visual index designed to be linear with respect to perceived visual air quality changes over its entire range in a way that is analogous to the decibel index for sound. The deciview scale is zero for pristine conditions and increases as visibility degrades. Each deciview change represents a perceptible change in visual air quality to the average person. Deciviews can be calculated from extinction data as follows: *Deciview (dv)* $= 10 \times \ln(b_{ext}(Mm^{-1})/10)$, where b_{ext} is total light extinction.

Visual range is an expression of visibility impairment defined as the distance in miles or kilometres at which a large, black object just disappears from view. Visual range values are calculated from direct measurement data, or are estimated directly by observers. Visual range can be calculated from extinction data as follows:
Visual Range (km) $= 3912 / b_{ext}(Mm^{-1})$

Source: http://www.phoenixvis.net/education.html

An AQHI form could incorporate any or all of the three goals mentioned in the previous section. For example, it could provide a measurable level of pollution which is unacceptable (i.e., no more than five poor days per year). It can also provide a metric for assessing excellent visibility and increasing the number of days in this category. Finally, reaching improved visibility on all days would be assessed by the distribution of days in each of the categories shifting towards better visibility.

One convenient part of an AQHI-like metric is that it could be applicable to urban, rural, and wilderness areas. As one expects better visibility in the less-populated areas, the number of days deemed acceptable in each category may be lower in the wilderness areas than the urban areas. However, the same metric of excellent and poor air quality would be usable to describe any area.

A visibility index can include both a quantifiable metric such as deciviews or visible range and a qualitative/human perception metric as well. For example, New Zealand's visibility index

(Ministry of Environment, 2000, 2001) provides a level of "off" colour perception as part of their metric. Example visibility index ranges used in New Zealand, Phoenix, AZ, and Denver, CO are provided in Table 3-1. Different metrics and averaging periods are used in the examples provided and there is a range of naming conventions as well. Like the AQHI, the intervals of visual range or visibility impairment do not need to be the same among all categories. Specific details regarding the form of the index, any cut-offs between day types, definition of exceptional events and how to handle them, and acceptable levels could be decided within the working group.

Table 3-1: Example Visibility Index Measures

Category	New Zealand	Phoenix, AZ	Denver, CO
Poor (also action, very poor, extremely poor)	<8 km and/or distinct "off" colour	≥29 deciviews	≥201 Mm^{-1}
Fair (also alert, poor)	< 20 km and discernible "off" colour	25-28 deciviews	101-200 Mm^{-1}
Good (also acceptable, moderate)	20-70 km and discernible "off" colour	21-24 deciviews	51-100 Mm^{-1}
Very Good (also good)	20-70 km and no "off" colour	15-20 deciviews	
Excellent (also good)	> 70 km and no "off" colour	≤14 deciviews	0-50 Mm^{-1}
Averaging periods	1-hr, 8-hr	4-hr, daylight	4-hr, daylight

The form and metric of the visibility indicator proposed by a report to the New Zealand Government (Ministry of Environment, 2000) is well worth considering for application in the LFV. While there are many components of that index that are specific to New Zealand environments, emissions and society, the guiding logic and some of the explicit structures are ones that will serve the LFV, B.C. and the rest of Canada in general very well.

The New Zealand Index (NZI), is actually an index of the risk of visibility degradation, but is based on a formulation that lends itself to implementation as an index that allows reporting, public communication and trend analysis, and is linked to emissions in a way that allows progress on emissions reduction strategies to be related to improvements in visibility. The visual ranges expressed in the index were developed as follows: 70 km was historically taken as representing almost perfect visibility; 20 km has been used by other countries as the defining line between 'good' and 'degraded' visibility; and 8 km is based on the concept, arising from meteorology, of visibility sufficiently degraded to require special care in some activities, such as aviation (Visibility in New Zealand, 2000). The NZI is:

1. Regionally calculated, so as to allow linkage between the index and regional air quality management plans,

2. Based on understanding the emissions of selected primary pollutants and pollutant precursors (NO_x and PM_{10} in the NZI case) and improving the emissions inventory for modelling efforts,

3. Depends on one or more subjectively determined weather/geography factors; includes "special factors" to account for particular circumstances such as local sources of uncontrollably emitted, naturally occurring visibility degrading substances (such as sea spray), or where emissions from one area (such as smoke from agricultural burning) can obviously impact on an adjacent one.

4. Based on a calibration between objective measures of visual range (inverse nephelometer backscatter; visual observations of distance or processed camera images (quantitative) and subjective appearance indicators (visual observations of colour by trained observers; casual observer/public complaint; qualitative camera image). Colour categories were defined as:

    a. "No 'off' colour" = no reasonable person would detect any departure from natural conditions,

    b. Discernible 'off' colour = a reasonable person would agree that some form of air pollution was discernible, but not necessarily affecting visual clarity significantly, and

    c. Distinct 'off' colour = a reasonable person would agree that air pollution was present, thereby decreasing amenity value.

A number of elaborations and extensions of the NZI could be considered for application in the LFV. Of particular local relevance would be the use of high resolution (space and time) emissions inventory data. This could facilitate the visibility indicator being applicable over fine spatial resolution (within the LFV airshed) and short time scales (possibly as low as a few hours). Also important would be giving special consideration to particular natural emissions. These include sea salt during high, onshore wind conditions and wind driven glacial silt in mid LFV during wintertime anticyclonic weather conditions. In the LFV, it would be possible to incorporate emissions of VOCs, and $PM_{2.5}$ as appropriate.

The resulting quantitative indicator of visibility will allow the monitoring to be aligned to air quality management plans and will provide the public with an understandable assessment criterion. The indicator could be structured in a way that is consistent with the AQHI, thus providing a uniformity of structure and aiding public interpretation of the measure. While useful for reporting visibility levels, these indicator levels do not provide an indication of the acceptability of visibility to the community. They could, however, be used as a guide for deciding whether further assessment of the acceptability of visibility levels to the community is needed.

Australia takes a similar approach but only includes visual range as the measure. A goal of 20 km was established as an indicator of good/bad visibility for most parts of Australia. The Phoenix visibility index uses deciviews which are also used for monitoring the protected Class I areas (i.e., national parks). Deciviews are a useful scientific tool because they have a linear scale and are independent of meteorology but are difficult to explain to the public; no human perception measure is included. Denver has a visibility index based on light extinction and only four categories were defined; no human perception measure is included. Visual range measures are easier for the public to understand than extinction or deciviews.

The dominant US visibility program is the Regional Haze Rule (RHR). For the RHR the EPA proposed presumptive ''reasonable progress targets,'' expressed in terms of deciviews, for the purposes of improving visibility on the twenty percent worst days and allowing no degradation of visibility on the twenty percent best days. Under the RHR, states are required to adopt progress goals for improving visibility from baseline conditions (represented by 2000 to 2004) to achieve natural background conditions within 60 years (represented by 2064) for all mandatory Federal Class I areas (i.e., 156 national parks and wilderness areas). Progress goals are to: improve visibility on the haziest (i.e., 20% worst) days, and ensure no degradation in visibility on the clearest (i.e., 20% best) days. If degradation in best visibility day conditions is observed over time, states will re-evaluate their emission reduction strategies. The reasonable progress goals must provide for a rate of improvement sufficient to attain natural conditions by 2064 (so-called glide path), or states must justify any alternative to this rate. States determine whether they are meeting their goals by comparing visibility conditions from one five-year average to another (e.g., 2000-2004 to 2013-2017). In setting the goals, EPA reviewed public perception studies conducted in the 1980s by the National Park Service (e.g., Chestnut and Rowe, 1990).

For Phoenix, Arizona, an Executive Order directed the Governor's Brown Cloud Summit "to establish options for a visibility standard or other method to track progress in improving visibility in the Phoenix area." The Summit concluded that a daily visibility index for the metropolitan area should have its characteristics defined through a public survey process. This process called for a representative cross-section of residents in the Phoenix metropolitan area, to determine what visual air qualities are desirable, what visual range is acceptable, and how often the combination of acceptable visual range and air quality is preferred. Through a series of meetings in 2002 and early 2003, the Arizona Department of Environmental Quality (ADEQ) and the Visibility Index Oversight Committee designed the visibility survey, selected a contractor to conduct the survey, oversaw the completion of the field portion of the survey, and defined a recommended visibility index. The Visibility Index Oversight Committee Final Report was issued in early 2003 summarizing the visibility index (available at http://www.phoenixvis.net/PDF/vis_031403final.pdf).

In Denver, Colorado, the Visibility Standard Index (VSI) is reported as the measure of visual air quality based on transmissometer measurements. The standard for visual air quality in Denver is 0.076 per kilometre of atmospheric extinction, which means that 7.6 percent of a light source's intensity is extinguished over a one-kilometre path. A violation occurs when the four-hour average extinction exceeds the 0.076 standard. The standard is in effect during the core daylight hours from 8 a.m. to 4 p.m., although extinction is monitored 24 hours a day. The Denver metro transmissometer instrument is housed atop a building downtown. The device is aimed at a light source of known brightness atop the Federal Building, one and one-half miles away. The transmissometer measures the intensity of the light source which is compared against the light's actual intensity. The difference represents how much light the atmosphere is absorbing or scattering. This difference is converted to a number on the VSI scale. Higher VSI values are associated with higher atmospheric extinction, hazier skies, and less clear air. Determining the actual VSI reading for a particular day can often be complicated by the presence of precipitation, relative humidity of 70 percent or greater, and the obscuring phenomena of fog. When such phenomena are present in the atmosphere, the VSI readings are excluded because they are not representative of the visual air quality problem. The scientist who designed this system has retired and was not available for an interview during this study period – it is not clear what role public perception had on setting the index levels.

A literature search of methods used for establishing visibility goals in other jurisdictions was conducted. Visibility is a prominent issue in many areas, particularly Europe, however most jurisdictions did not have any visibility goals (see Table 3-2).

Table 3-2: Regions Without Visibility Goals

Austria	Finland	Lithuania	Singapore
Belgium	Germany	Malaysia	South Africa
Czech Republic	Hong Kong	Mexico	Sweden
Denmark	Indonesia	Norway	Thailand
Egypt	Israel	Poland	United Kingdom
Europe	Japan	Saudi Arabia	

3.4 OTHER CONSIDERATIONS

Consideration is needed to determine how to discern between manmade and natural events that affect visibility – and account for them in the index or in the achievement of progress toward the overall goal. For example, fires can be anthropogenic (i.e., prescribed or agricultural burns), or natural, and distinguishing between the two is a difficult task.

Whether fires are natural or anthropogenic can be difficult to discern since there is no unique tracer in the ambient air that distinguishes the two, and the impact on visibility and ambient concentrations may be similar. Thus, other data analyses or modelling are needed to better understand natural vs. anthropogenic impacts on a case study basis. For example, for a given fire event, an analysis using land-use data of the fuel mixture may indicate whether a wildfire was likely, and coordination with local officials to understand if there were controlled burns in the area would be needed. The SMARTFIRE (Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation) tool, which integrates land use and modelling, can be used as an initial assessment of whether fires are natural or anthropogenic. Once a summary of whether each fire was natural or anthropogenic is made, analyses could be conducted to quantify the impact between the two types. Modelling could also be performed to understand whether differences in fire management practices, even if the same amount of wildfires occurred, would help improve visibility. Lastly, a consistent definition of anthropogenic fires is needed. For example, in this discussion, anthropogenic means "prescribed", though there is debate about whether wildfires should also be considered partially anthropogenic due to past fire management practices (such as fire suppression). The WRAP has been involved in these discussions and the associated emission inventory development.

Other natural phenomena, such as fog and rain need to be excluded from consideration as agents affecting visibility. In addition, since visibility is primarily a daytime concern, consideration should be given to basing the metric on daytime average only, which is done in Denver and Phoenix.

4.0 DEVELOPING SCIENCE AND SOCIAL SCIENCE PROGRAMS

A visibility index for urban, rural and wilderness areas (see text box) could employ different metrics, measurements, and forms of tracking to those classifications, as shown in Table 4-1.

Table 4-1: Key Considerations in Visibility for Urban, Rural, and Wilderness Areas.

Component	Urban	Rural	Wilderness
Goal	Improve visibility	Improve visibility	Return to natural background?
Metric	Quantitative + human perception	Quantitative; human perception optional?	Quantitative
Measurements:			
Quantity	A number of sites; more frequent measurements	Single site; less frequent measurements	Single site; less frequent measurements
Pollutants	Continuous gaseous & $PM_{2.5}$; filter-based PM species	Continuous $PM_{2.5}$; special studies filter-based measurements	Filter-based $PM_{2.5}$
Meteorology	Full surface complement (WS, WD, T, RH); consider upper air measurements	Full complement (WS, WD, T, RH)	Full complement (WS, WD, T, RH)
Direct measures	Continuous optical measure (extinction, scatter, or transmission) extinction components, camera	Continuous optical measure	Continuous optical measure (e.g., nephelometer)
Public perception measure	Valuation and perception survey	Valuation and perception survey	None?
Tracking:			
Other goals that could be met with visibility measurements	Assessing trends, tracking progress toward goal, source apportionment, supporting airshed management and planning	Supporting airshed management and planning	Assessing background concentrations, deposition, international transport, and smoke impacts

Part of the reason for considering these areas differently is the expected differences in emissions density and homogeneity. For example, an urban area will usually have a more complex mixture of emissions, higher emissions density, and greater spatial differences in pollutant concentrations than rural or wilderness areas. The considerations put forth in the table are provided to initiate discussion at the workgroup and stakeholder level.

4.1 SCIENCE PROGRAMS

Scientific tools and methodologies needed to measure, track, and model visibility impairment are available and reasonably well-developed and documented. The scientific tools need to implement a visibility management program are documented in Table 4-2.

Table 4-2: Inventory of Key Tools for Implementation of a Visibility Management Program

Tool	Key Components
Monitoring Tools	Composition: Speciated PM measurements Optical characteristics (nephelometers, transmissometers, teleradiometers, etc.) Digital images of visibility conditions
Data Analysis Tools	Trajectory analysis (e.g., good vs. poor visibility days) Source apportionment (positive matrix factorization - PMF or chemical mass balance - CMB) Reconstructed light extinction, Trend analysis
Emission Inventories	Point sources (large industrial facilities) Mobile sources (on-road and non-road) Area sources (ubiquitous small sources like gas stations) Wildfires, Dust
Modelling Tools	Community Multiscale Air Quality model (CMAQ) California Puff model (CALPUFF) – plume analysis A Unified Regional Air Quality Modelling System (AURAMS) Global Environmental Multi-Scale Air Quality Model (GEMAQ)
Public Perception Tools	WinHaze, Surveys of different stakeholders

4.1.1 Monitoring Tools

Many US experts specifically noted the vital role of the Interagency Monitoring of Protected Visual Environments (IMPROVE) speciated particulate network in the US for developing reduction strategies and tracking progress towards meeting a visibility goal. First, speciated measurements allow the creation of a reconstructed visibility metric such as extinction or visual range that can be made *independent of meteorology*. Meteorology is a key effect, since visibility is impacted by relative humidity, which changes as a function of season and can vary substantially interannually. In addition, speciated measurements are necessary to assess the emission sources responsible for haze. Finally, speciated measurements can indicate which parts of visibility are controllable (i.e., from anthropogenic sources under local or regional control) or beyond control (i.e., transported pollution, wild land fires, or natural background). Identical urban/rural/wilderness monitoring set-ups are needed for ease of comparison and for use in assessing transport. These measurements are useful for monitoring objectives other than visibility determinations as well (e.g., establishing background concentrations, performing source apportionment, assessing transport, tracking trends).

The optical properties of the atmosphere are predominantly determined by PM. Therefore, optical monitors are good for testing if the extinction calculations are accurately tracking visibility changes. Nephelometers and other continuous measurements are an excellent way to track the extinction relationship between $PM_{2.5}$ and visibility. Co-located measurements of light scattering, relative humidity, and $PM_{2.5}$ concentrations can be used to develop a relationship between $PM_{2.5}$ and light scattering (a key component of extinction, which is the sum of scattering and absorption). When the data correlate well, continuous $PM_{2.5}$ measurements could be used to estimate light scattering at locations without nephelometers. Transmissometers measure the transmission of light including both particle and gaseous contributions – this method is helpful when NO_2 concentrations, for example, are of concern. Teleradiometers can be used which provide a continuous measurement of extinction but they are very expensive.

Finally, digital images have become relatively inexpensive and can be updated to provide a visual image of the key vistas important for assessing visibility through public perception studies. Automated digital images from digital cameras are now routinely operated for keeping a visual record of visibility. These images can be analyzed using image processing software to determine changes in visibility over time. Images can also be used in public outreach.

4.1.2 Data Analysis Tools

After collection of monitoring data, a number of data analysis tools and techniques are available to help identify and characterize visibility issues. Trajectory analysis investigates the meteorological patterns on days with good visibility and/or poor visibility to determine the corridors through which air parcels travel. This analysis can help indicate where emissions sources are currently located that are responsible for poor visibility and can also indicate the places that need to be kept free of emissions to maintain good air quality days. For example, analysis combining ambient data, emission inventory, and trajectory information can help identify both clean air corridors that are critical to protect as well as regimes that produce poor air quality. Figure 4-1 shows an example for a rural site in Missouri. In the example, the blue bars represent areas that need to be protected to ensure that good visibility days do not deteriorate while areas with red bars indicate areas where targeted emissions reductions may have the greatest impact on poor visibility days. These analyses are best suited for regional scale assessments given the resolution currently available from models such as Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) but more finely gridded meteorological wind fields could be developed for smaller airsheds. Trajectory analysis can also identify meteorological patterns under which visibility degradation is more likely to occur.

Source apportionment, also known as receptor modelling, is a useful tool for understanding the impact of sources on ambient pollution and visibility. Receptor models are often compared to the more typically used dispersion models that disperse pollutants using chemical, meteorological, and emissions information to determine ambient levels of various chemical species at a receptor site. Receptor models do not require these inputs and instead use ambient measurements at the monitoring site to determine the contributions of the various sources to levels measured at the receptor. Chemical mass balance (CMB) and positive matrix factorization (PMF) are two methods that have been successfully used in source apportionment of $PM_{2.5}$ (Brown et al., 2007; Hwang and Hopke, 2006; Kim et al., 2003; Kim and Hopke, 2004; Kim et al., 2004; Lee et al., 2002; Pekney et al., 2006; Poirot et al., 2001; Polissar et al., 2001; Ramadan et al., 2000; Song et al., 2001; Yakovleva et al., 1999; Zhou et al., 2004; Zhao et al., 2004; Watson et al., 2001). The two models require different inputs, make different assumptions, and have different limitations as shown in Table 4-3. The limitations of each of these methods can be overcome by applying both methods to a given data set, with overlapping results providing additional confidence.

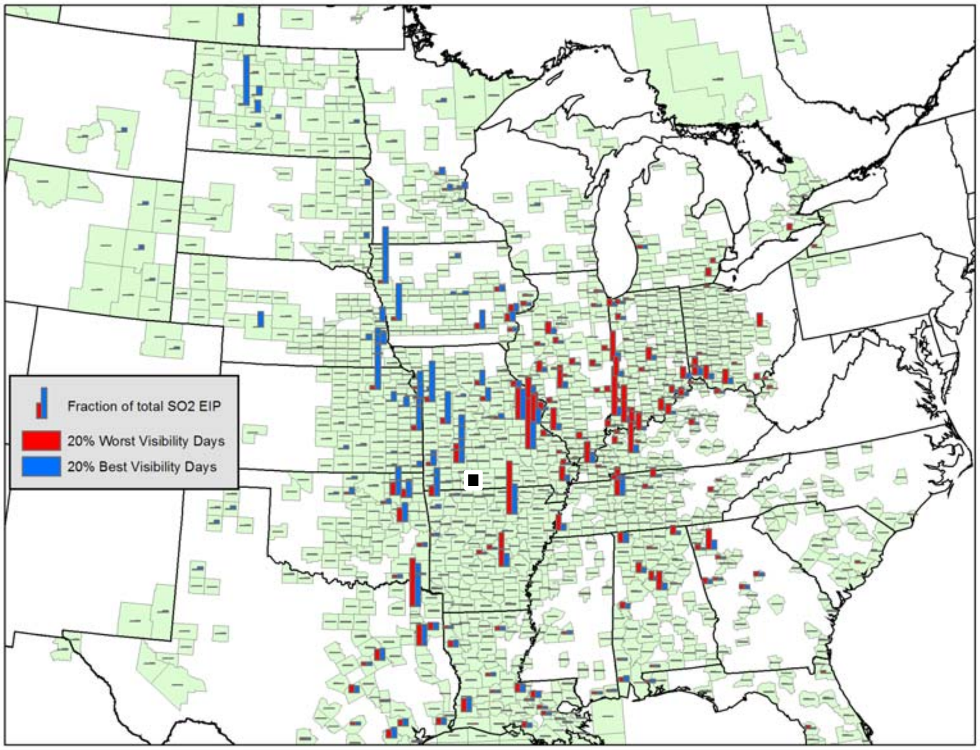

Figure 4-1: Emission impact potential (emissions weighted by trajectory transport density) of SO_2 for the 20% best and 20% worst visibility days for Hercules-Glade, Missouri.

Reconstructed light extinction analysis basically uses the components of particulate matter to calculate visibility metrics like visible range or deciviews without the influence of meteorology. Aerosol species that affect visibility are often hygroscopic, meaning that their growth is dependent on atmospheric humidity. As such, the effects of ambient meteorology can not be totally removed from the calculations of visibility degradation due to particulate species. In this case, to remove the influence of meteorology means to remove scattering due to naturally occurring liquid water in the atmosphere.

This type of analysis is important for assessing long-term trends without the inherent variability of meteorological parameters. It also helps regulators identify the components, and eventually the sources, that most impact visibility extinction. Studies in the US have been conducted on local, regional, and national scales (Gebhart et al., 2001; Malm, 1979, 2000; Malm and Day, 2000; Sullivan, 2004; Western Regional Air Partnership and Central Regional Air Planning Association, 2004).

Table 4-3: Comparison of CMB and PMF source apportionment methods.

	CMB	PMF
Input	Source profiles[a], ambient data[b]	Ambient data[b]
Assumptions	Source emissions are constant	Source emissions are constant
	Chemical species do not react	Chemical species do not react
	All sources are identified	
	No collinearity in profiles	No collinearity in profiles
Limitations	Sources must be identified prior to applying model	Factors are difficult to interpret
	Source emissions are not constant	Factors do not always represent a single source
	Species react	Emissions are not constant and species react

[a] Source profiles are the fractional contributions by species to total emissions from a given source.

[b] The required ambient data set is a matrix of concentrations with columns representing the chemical species and the row representing the time.

Trend analysis is a simple test to determine if changes are occurring in visibility (or underlying visibility reducing pollutants) over time. Trend analysis is important for checking progress and determining the success of control measures aimed at improving visibility. This allows regulators and stakeholders to hold regulations "accountable", and adjust regulations as needed over time to ensure goals are being met.

4.1.3 Emission Inventories

Emissions inventories of the sources of pollutants that contribute to poor visibility are a necessary part of the process of implementing a visibility management program. Key contributors such as sulphur dioxide, nitrogen oxides, dust, fires, and various combustion by-products that contribute to organic carbon and elemental carbon are all needed. Given the Lower Fraser Valley's location, international emission inventories may be needed in order to characterize the pollutants from the US border area. Currently, the emission inventory for the Lower Fraser Valley includes Whatcom County but information on emissions elsewhere in the

Georgia-Basin Puget-Sound Region may also be required. Nonetheless, the 2005 Lower Fraser Valley emission inventory will be a good starting point for the Lower Mainland. However, emission inventories will need updating or refining for the rest of the province. An analysis of the emission inventory of key pollutants can help to identify the portion of pollutants that are available to be reduced through control measures and technologies. The inventories are also vital for use in modelling tools to consider the effects of changes in emissions on the formation of secondary PM.

Emissions inventories are often broken into multiple component pieces. These pieces are typically identified as point or stationary sources, area sources, mobile sources (sometimes split between on-road and non-road sources), and natural or other sources. Point sources are large industrial sources such as power plants, refineries, or manufacturing plants. Area sources are ubiquitous, small sources, such as gas stations or household emissions sources, and the 2000 British Columbia emission inventory also included prescribed burning and residential wood use. Mobile on-road sources are comprised of cars, trucks, and heavy-duty diesel vehicles. Non-road mobile sources include construction equipment, airplanes and airports, marine vessels, and off-road vehicles. Other sources include wildfires, wind-blown dust, and plant (biogenic) emissions. Creating these emission inventories is a key input for the air quality models needed to predict the outcomes of emission reductions on visibility. The US Western Regional Air Partnership (WRAP) has expended considerable effort to develop emission inventories in support of the Regional Haze Rule and much of what they have developed could be applicable to British Columbia, particularly for wild fires.

4.1.4 Modelling Tools

Community Multiscale Air Quality model (CMAQ), A Unified Regional Air Quality Modelling System (AURAMS), and the Global Environmental Multi-Scale Air Quality Model (GEMAQ) are regional-scale air quality models that can be used to predict the impact of emission reductions on visibility. CMAQ has been used in the US as part of regionally coordinated visibility plan. AURAMS and GEMAQ are Canadian regional-scale air quality models that are roughly equivalent to CMAQ and may be the preferred local tool. Regional-scale air quality models use emission inventories as inputs. The air quality models then predict the resulting pollutant concentrations from these emissions. Comparisons of future-year emission scenarios based on differing control strategies are then run to compare how future-year pollutant concentrations will change. The pollutant concentrations that most affect visibility can be used to construct a visibility metric using the reconstructed extinction calculations explained in the data analysis tools section. For example, light extinction analysis of modelled particulate concentrations techniques can also be used to assess visibility degradation along paths of interest. This "Line of Sight' technique has been used to assess visibility degradation and enhancement associated with various emission control scenarios in Southwestern British Columbia using CMAQ as the particulate model (Qiu et al., 2006).

In addition, simpler models like the California Puff model (CALPUFF) can be used to assess the effects of individual plumes for major source categories. This can be important if individual sources are found to be contributing plumes that impact visibility. CALPUFF was used in the Northeastern US to help identify and quantify the impact of the large individual sources that were impacting local-scale visibility. The CALPUFF model has also been applied to determine a Haze Index based on the deciview for the Visibility Improvement State and Tribal Association of the Southeast studies in the US (VISTAS, 2005).

4.2 SOCIAL SCIENCE PROGRAMS

Because visibility is generally the most noticed effect of air pollution, the public may judge the effectiveness of air quality management initiatives by the transparency of the air. This may well be so even if the management initiatives are driven primarily by air quality health effects. It is a universal truism that visibility is a primary and highly obvious indicator of general air quality: "*If you can see the air, it is polluted; if you cannot see the air, it might still be polluted.*" In this sense, all citizens carry two air quality monitors around with them. The challenge arises from the fact that the output of these sensors is conditioned by the individuals' perceptions, values and attitudes.

4.2.1 Human Perception of Visibility and Air Quality

While visibility is primarily an amenity issue, the way this amenity is valued varies highly with region (Malm et al, 1981). This variability is conditioned by local conditions, the presence of scenic vistas, and the importance of (polluting) industries to the local economy (and employment). Community surveys conducted in New Zealand revealed that while the general public view maintaining good air quality to be extremely important, they believe that their own activities have little effect on air quality. It is for these reasons that regulatory agencies must understand public perceptions of air quality in their region. This understanding can only come about through the conduct of public perception surveys such as those conducted in the LFV (Pryor, 1996; McNeill and Roberge, 2000), and further exemplified by studies in New Zealand (Petersen et al, 1997) and Denver, Colorado (Ely *et al.*, 1990).

There are a range of instruments (surveys, stakeholder groups, focus groups, public workshops etc) for determining public perception and valuation of visibility. These are examples of techniques applied in the social sciences for valuing non-market goods (including views and landscapes) that have been developed over the last two decades. Environmental valuation methods divide into revealed and expressed preference methods and sophisticated approaches have been developed for aggregating the responses of samples up to a full population. Revealed preference methods include Hedonic Pricing, which assumes that expenditures on consumption can be used as a proxy for the value of a non-market good; a simple example would be the value of a view property as opposed to an identical non-view property in a real estate market. Expressed preference methods solicit responses from survey participants using ranking methods or willingness to pay studies. An essential part of the development of a visibility goal for any region is the employment of a public perception and valuation instrument (or instruments) that is selected as appropriate for the region. In the LFV, this selection will be enhanced by a review of existing methods applied in the LFV and elsewhere in relation to the growing body of literature on valuing non-market goods.

4.3 First Nations Perception and Valuation of Visibility

The First Nations have a very particular cultural relationship to their environment. Much of this relationship is captured in various aspects of Indigenous Knowledge. An explicit expression of this relationship is the First Nations Environmental Stewardship Action Plan (Anon, 2005). While this action plan explicitly defines the First Nations' intended "development of an environmental stewardship / management / care strategy that is First Nations designed and controlled, holistic, and reflective of the diversity of First Nations cultures and knowledge", it does not target visibility as a specific concern. What is specifically targeted in many First Nations' environmental initiatives is degraded air quality.

There can be no doubt that the First Nations, as a sector of Canadian Society, are vitally concerned with all aspects of their physical, chemical, biological and social environment. That concern includes air quality, and it is reasonable to assume that such concern extends to issues of visibility. The substance and nature of those concerns have not been investigated to date. As we move to develop, implement and manage visibility goals for the LFV, it is imperative that local First Nations' concerns and attitudes be incorporated into those goals. An important consideration may be the idea of "First Nations Viewscapes" as environmental features that must be protected. These ideas can only be achieved by engagement with the First Nations, and their explicit and possibly special participation in the public studies of valuation and perception of visibility as an environmental resource.

5.0 IMPLEMENTING A VISIBILITY MANAGEMENT PROGRAM

The most efficient and effective way to implement a visibility management program would be to integrate it with existing air quality management systems in the province. One of the key ways air quality is managed in B.C. is through community airshed planning. The Provincial Framework for Airshed Planning (MOE 2008) and associated website tool incorporate visibility goals, indicators and targets into community airshed planning process. The following communities have airshed plans in place:

- Metro Vancouver
- Fraser Valley Regional District (FVRD)
- Bulkley Valley-Lakes District (BVLD)
- Prince George
- Quesnel
- Regional District of North Okanagan (RDNO)
- Regional District of Okanagan-Similkameen (RDOS)
- Sea-to-Sky Region
- Williams Lake

Metro Vancouver has clearly indicated that improving visibility is important by making it one of only three goals in its 2005 AQMP. As Metro Vancouver has regulatory authority for air quality in its region, it could adopt a visibility objective or index. In all other jurisdictions of B.C., the MOE has regulatory authority and therefore it would need to adopt a provincial visibility objective or index that other communities could adopt in their airshed plans. An example visibility goal could easily be added to Step 5 of the online air quality planning tool (http://www.airqualityplanning.ca/). Notwithstanding their lack of regulatory authority, all communities could adopt a visibility goal in their airshed plans.

A visibility management framework also needs to consider outreach, integrating with other air quality goals, and monitoring and data analysis. As discussed in Section 3.3, adopting a format for the visibility index that is similar to the AQHI and potentially integrating it with the AQHI would likely accelerate public acceptance. In any case, use of a website to inform the public of the visibility goal and to track progress is highly recommended. Consideration could also be given to providing this information to other media (newspapers, television etc.) as is done currently for the Air Quality Index. Public perception is an important component of any visibility goal. Cameras could be used real-time to give the public access to visibility information for a given location. On the web, a discussion of the links between visibility, measured parameters, and photos could be a useful tool.

Since a number of air quality regulations and goals already exist, and these will be complementary to any visibility management program, visibility goals should be integrated with other air quality goals, especially $PM_{2.5}$. Reductions in other pollutants can have co-benefits for visibility and should be included. In particular, a visibility monitoring network could be added to existing networks with other air pollutants to meet a broader range of goals. Speciated $PM_{2.5}$ data, collocated with meteorology and other measurements, will be critical to help regulators and analysts understand the impacts of specific components and sources on visibility. In this way, existing air quality regulations, monitoring and analyses can be leveraged with the visibility framework.

Results from these additional monitoring efforts will need to be analyzed to both better understand the nature of impaired visibility and to justify them. The new data should be examined in the context of other similar data collected throughout B.C. and the rest of Canada, as well as being “mined” to better understand the potential causes of haze. Specific analyses could include reconstruction of visibility extinction, source apportionment, trajectory analysis, and comparison with emission inventory/modelling analyses.

6.0 ANALYSING DATA AND TRACKING PROGRESS

An analysis of existing data is needed at the onset of the process to understand current conditions (e.g., pollutants contributing to visual impairment, likely sources of interest, number of days within certain visual ranges) and is also required periodically to track the progress of the visibility management program. Tools for data analysis were discussed in Section 4.

The frequency of analyses to track progress should be set as part of the overall timeline for reaching visibility goals. In establishing a 60 year goal for the US Regional Haze Rule, the timeline was determined based on analysis of trends in visibility at existing sites and an end goal of returning conditions to natural background. Most programs reviewed seem to be calling for assessment of progress every 5 years. For B.C., it may be reasonable to call for progress during a 5 year period and provide a definition of progress (e.g., some % fewer poor visibility days) with which to measure against. However, unless the trends are large enough, significant progress over a 5-year time span may be difficult to quantify.

In addition to tracking ambient trends in visibility and components of extinction, changes in emissions from sources most important for pollutants identified as being dominant contributors to haze should also be tracked. It is vital to have good emission inventories that are periodically updated. Costs of preparing, updating, and maintaining these emissions inventories should be mitigated somewhat by the need for these same pollutants for health issues for particulate pollution.

Also as part of progress assessment, periodic review of the actual goals should be made. Original visibility targets may not be achievable because of changes not accounted for in the goal-setting process. For example, consider the possible impacts of external influences such as climate change, the pine beetle, transported pollution, changes in natural resource management, and changes in fire management practice.

7.0 SUMMARY OF RECOMMENDATIONS

7.1 FRAMEWORK OF A VISIBILITY GOAL

The framework of protecting visibility in British Columbia and in other regions in Canada should be a stepwise process of setting visibility goals, selecting the form/metrics of the goal, implementing a program, and tracking progress/reassessing the goals (see Figure 2-1). As the program matures, each step can be revisited to adjust to new findings and environmental conditions. Each step may begin with or include public outreach and stakeholder participation.

A minimum of two years of data should be collected to complete the first cycle and then we recommend the cycle be repeated every five years.

7.2 FORM AND METRIC OF A VISIBILITY GOAL

We recommend that a locally adapted form of the visibility indicator called NZI in section 3.3 be developed for implementation in the LFV. That indicator utilizes both objective and subjective measures of visibility, and can easily be adapted to local conditions, including consistency of reporting form with the AQHI.

As part of this approach, a **visibility index**, akin to the AQHI, could be developed to include both a quantitative measure of visibility and public perception with visibility conditions binned among a number of categories (e.g., poor, moderate, good, very good, and excellent). Specific details regarding the form of the index (i.e., visual range, extinction, deciviews), any cut-offs between day types, definition of exceptional events and how to handle them, and acceptable levels could be decided within the working group.

Visibility goals should be set using workshops and consultation with important stakeholders to obtain **consensus**. Three goals are the most likely candidates for improving or protecting visibility:

1. Limit the number of poor visibility days (Denver's visibility threshold, or the Regional Haze Rule's bottom 20% component)
2. Increase or maintain the number of excellent visibility days (Phoenix goal to improve excellent visibility days, Regional Haze Rule's cleanest 20% component)
3. Improve visibility on all days (Phoenix goal to shift the distribution from poor visibility days to good and excellent visibility days).

These goals are applicable to a range of areas and can be tailored specifically for them. Periodic review of the goals should be built into the framework. Targets may not be achievable because of changes not accounted for in the goal- setting process. For example, consider the possible impacts of external influences such as climate change, the pine beetle, transported pollution, changes in natural resource management, and changes in fire management practice.

7.3 SCIENCE AND SOCIAL SCIENCE PROGRAMS

7.3.1 Methodologies critical to development of a goal:

A significant effort should be expended on data analysis to establish, and ultimately monitor, a visibility goal. The following analyses are recommended to provide a sound scientific platform from which to work:

- Perform data analysis of existing $PM_{2.5}$ speciated (and selected gaseous) data to understand current conditions. Analyses include estimating extinction, understanding composition, inspecting trends (if the data record is long enough), assessing the frequency of smoke events, and assess the relative importance of NO_2 to visibility impairment.
- Review on-the-books air pollution mitigation plans (e.g., Metro Vancouver AQMP) considering their potential impacts on visibility.
- Review emission inventory and projections of the inventory considering their potential impacts on visibility.
- Assess the LFV and Provincial networks with regard to monitoring visibility.
- Evaluate the effectiveness of recently set visibility goals in Denver, Phoenix, and New Zealand.

7.3.2 Science Program Needed To Provide Support For The Goal

The science program needed to provide support for a visibility goal includes measurements components as summarized in Table 7-1.

Table 7-1: Visibility Framework Measurements in the Context of a Science Program

Measurements	Urban	Rural	Wilderness
Quantity	A number of sites; more frequent measurements	Single site; less frequent measurements	Single site; less frequent measurements
Pollutants	Continuous gaseous, $PM_{2.5}$; filter-based PM species	Continuous $PM_{2.5}$; special studies filter-based measurements	Filter-based $PM_{2.5}$
Meteorology	Full complement surface (WS, WD, T, RH); consider upper air	Full complement surface (WS, WD, T, RH)	Full complement surface (WS, WD, T, RH)
Direct measures	Continuous optical measure (extinction, scatter, or transmission) extinction components; camera?	Continuous optical measure	Continuous optical measure (e.g., nephelometer)
Public perception measure	Colour, survey?	Colour?	None?

The program needs to include a feedback loop of data collection, data analysis, data sharing, and data evaluation. Regularly updated emission inventories for the Lower Fraser Valley and the province are key to managing visibility. Models can also help understand the impacts of various sources.

7.3.3 Social Science Program Needed To Provide Support For The Goal

We recommend the development of a social science program needed to provide support for the visibility goal. This program is an essential part of the development, implementation and management of a visibility goal. The program should:

1. Be based on a thorough review of studies of public perception to date, both in LFV (especially Pryor (1996), McNeill and Roberge (2000) and McNeill and Roberge, 2007), and in other jurisdictions.

2. Incorporate all applicable results from the review into a coordinated and focussed study of public perception and valuation of visibility in the LFV, using recently developed social science methods for valuing non-market goods.
3. Make every effort to incorporate First Nations into all survey groups. Parks Canada works to protect heritage viewscapes, and this can logically be extended to First Nations cultural viewscapes. The idea is new, and does exist in some materials on the McKenzie Valley pipeline hearings of 2006. Most importantly, it must be up to the First Nations to determine what are cultural viewscapes that must be protected. To achieve this will require collaboration from First Nations, and guidance from cultural anthropologists
4. Establish a cultural anthropological study to determine particular ways First Nations people view and value visibility as a resource.

In acting on these recommendations it is imperative that the studies be undertaken by social scientists qualified to deal with the theoretical and qualitative data analytical questions implicit in the analyses. One possibility would be to draw on resources available through the Centre for Indigenous Environmental Resources http://www.cier.ca/ .

7.4 Implement the Visibility Management Program

The visibility management program should be integrated with existing air quality management systems in the province such as the community airshed planning process. Communities with airshed plans in place and those that are in the process of developing a plan could incorporate visibility goals using the form and metric developed for the province.

Implementing the visibility management program will also require public outreach. Adopting a format similar to the AQHI and potentially integrating it with the AQHI would likely accelerate public acceptance.

Use of the internet to inform the public of the visibility goal and to track progress is highly recommended. Other media (newspapers, television, radio) could also be used.

Visibility goals should be integrated with other air quality goals, especially $PM_{2.5}$ emission reductions and monitoring.

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