Air Quality Report:

Analysis of Smoke Pollution Survey Results & Airshed Planning

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Executive Summary

This report is intended for use by the City of Campbell River, the public, and any local groups who have a vested interest in the health of the airshed in Campbell River. In addition to a historical overview of air quality efforts in the community, air quality monitoring data from a mobile device and an ambient air quality monitoring station has been collected and compared. Results support that Campbell River's air quality ranks among the best in British Columbia, however, there are hotspots where wood smoke pollution tends to accumulate and efforts to reduce local impacts are important at the municipal level.

While this report focuses on wood smoke pollution primarily from wood burning appliances, the discussion also touches on other air quality initiatives identified in the BC Air Action Plan that are ongoing in Campbell River. Initiatives include programs to reduce idling and greenhouse gas emissions, as well as urban forest management planning.

Acknowledgements

The author researched and wrote this report while on a Co-op work term with the City of Campbell River. This report is one aspect of the City of Campbell River Provincial Wood Stove Exchange Program. The author would like to thank the program's team members and partners for their assistance and contributions (Refer to Appendix I for a complete list of team members and partners). The author would also like to acknowledge the assistance of colleagues at the City of Campbell River, particularly Terri Martin and Amber Zirnhelt. Earle Plain, Air Quality Meteorologist for the Coast Region has been an important advisor to the project and his expert advice has been most appreciated throughout the preparation of this report.

Feedback and Questions

If you have feedback or questions about the report please contact the City of Campbell River's Sustainability Department at terri.martin@campbellriver.ca or (1) 250-286-5711.

Cover Illustration – Smoke in Campbell River from wood heating. View near Beaver Lodge Lands on February 20th, 2011. Photo: Jennifer Peters

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1 Introduction

In Campbell River, one of the most reported air quality issues by residents is from smoke pollution. Located at the 50th parallel and the third largest community on Vancouver Island, Campbell River's growing population may be at increased risk of exposure to elevated levels of air pollution as potential pollution sources increase. With just over 31,000 (2011 Census) in population and an average growth rate of 1.4% per year, Campbell River may see an increase in the use of solid fuel burning appliances along with development, exposing more people to wood smoke pollution.

Clean air is fundamental to quality of life in Campbell River. Air quality programming around wood smoke pollution has been an integral part of City and community planning since 1994 and this report focuses on recent efforts to monitor wood smoke pollution through the City's participation with the Provincial Woodstove Exchange Program. While wood smoke pollution reduction efforts continue, air quality programming has grown to include Idle Free initiatives, greenhouse gas emissions reductions and recent efforts branching into urban forest management. These programs are summarized in the discussion section of the report.

2 Background

Managing air quality is important due to the potential impacts to human health, the environment and the economy. Poor air quality in general has been linked to many adverse health effects such as breathing difficulties, exacerbation of allergies, aggravation of respiratory or cardiovascular conditions, and in severe cases, premature death (Brunekreef & Holgate, 2002; Government of BC, 2008). Populations vulnerable to poor air quality include children, seniors and those with respiratory illnesses (Gage & Saha, 2006). The Provincial Health Officer's 2003 report on air quality and public health in BC found that poor air quality (air pollution) can lead to an estimated $85 million increase in health care costs and as many as 250 premature deaths every year. Environmental impacts of air pollution include effects on vegetation health and productivity, poor visibility due to smog, as well as contributing to global climate change (Environment Canada, 2010b; Government of BC, 2008). Residential wood smoke is one contributor to air pollution.

Hardest-hit are valley communities where temperature inversions prevent wood smoke from being dispersed, and keep the smoke right where we live and breathe (BC Lung Association, 2011). An inversion occurs when warm upper air acts like a lid to hold surface air and smoke near the ground; the inversion and the valley walls trap pollution (See Figure 1).

Figure 1: A temperature inversion in a valley. The arrows symbolize the colder air being pushed down to the surface by warmer air (BC Air Quality, 2011).

3 Air Pollutants of Concern

3.1 Fine Particulate Matter ($PM_{2.5}$)

Smoke pollution is measured through levels of fine particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$). These fine particulates are the primary air pollutant of concern in BC due to their miniscule size and highly toxic nature. As $PM_{2.5}$ is easily inhaled, it can penetrate deep in the airway and lungs, leading to chronic respiratory and cardiovascular conditions (BC Lung Association, 2011; BC Provincial Health Officer, 2004). Sources of $PM_{2.5}$ vary across BC, but the three main contributors are prescribed burning, forestry operations and residential woodstoves. Transportation also contributes, especially in more densely populated areas. Figure 2 shows the relative contributions from various sources in BC.

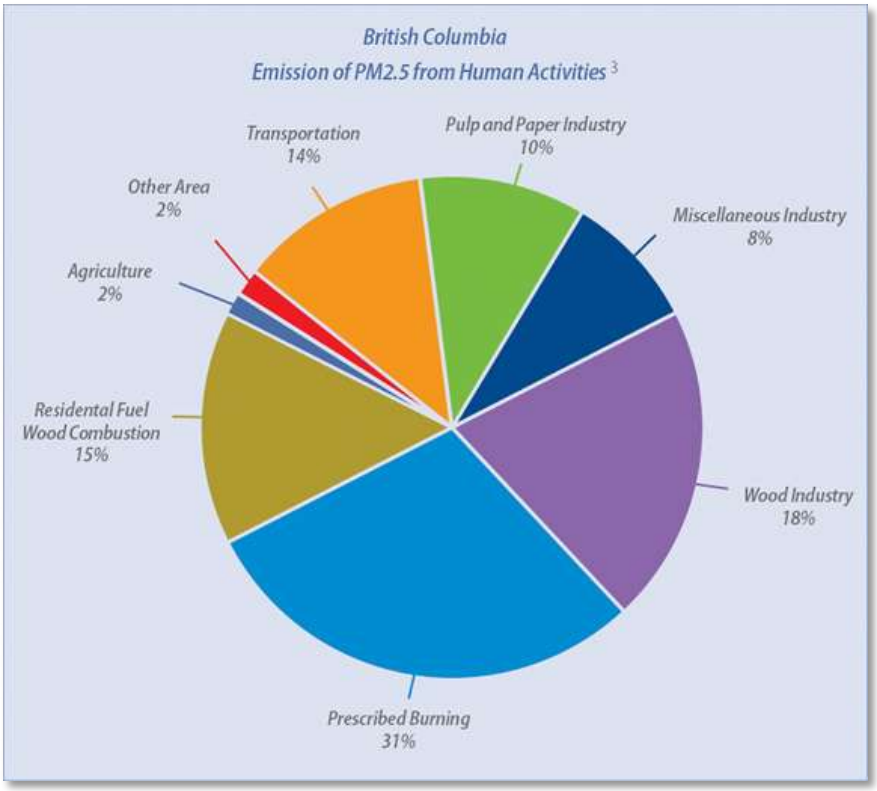

Figure 2: Sources of BC $PM_{2.5}$ from human activities based on Ministry of Environment emissions inventory data for the year 2000 (BC Government, 2008).

In Campbell River, $PM_{2.5}$ is measured by a Tapered Element Oscillating Microbalance (TEOM) Device at the Dogwood ambient air quality monitoring station (Figures 3 and 4). This equipment has been operating since 1995. Air quality measurements are available to the public on a near real-time basis on the bcairquality.ca website.

The Ministry of Environment upgraded the TEOM at the Dogwood site to a Federal Reference Method Beta Attenuation Monitor (FEM) in December 2012. It is known that the TEOM under-reports true $PM_{2.5}$ concentrations, particularly during the colder months. With the change-over to a FEM monitor, it is expected for $PM_{2.5}$ concentration to increase 20% or more in the coming years (E. Plain, personal communication). The reason that the TEOM $PM_{2.5}$ readings are lower is that the sample air is heated which drives off the volatile component of the $PM_{2.5}$ which artificially lowers the values.

Figure 3: Instrument at Dogwood ambient air quality monitoring station (Plain, 2011).

Figure 4: Dogwood ambient air quality monitoring station at 600 Westmere Rd indicated by the yellow push pin marker (Plain, 2011).

The Ministry of Environment compares $PM_{2.5}$ and other ambient air quality readings to air quality objectives to determine acceptability of air pollution levels in communities. For $PM_{2.5}$, the BC Ambient air quality objectives are 8µg/m^3 (annual average) and 25µg/m^3 (24-hour average). The BC Lung Association summarizes air quality monitoring measurements from ambient air quality monitoring stations around the province and reports their findings annually. From these summaries, Campbell River's air quality ranks among the best in the best in the province (Figure 5) (BC Lung Association, 2013).

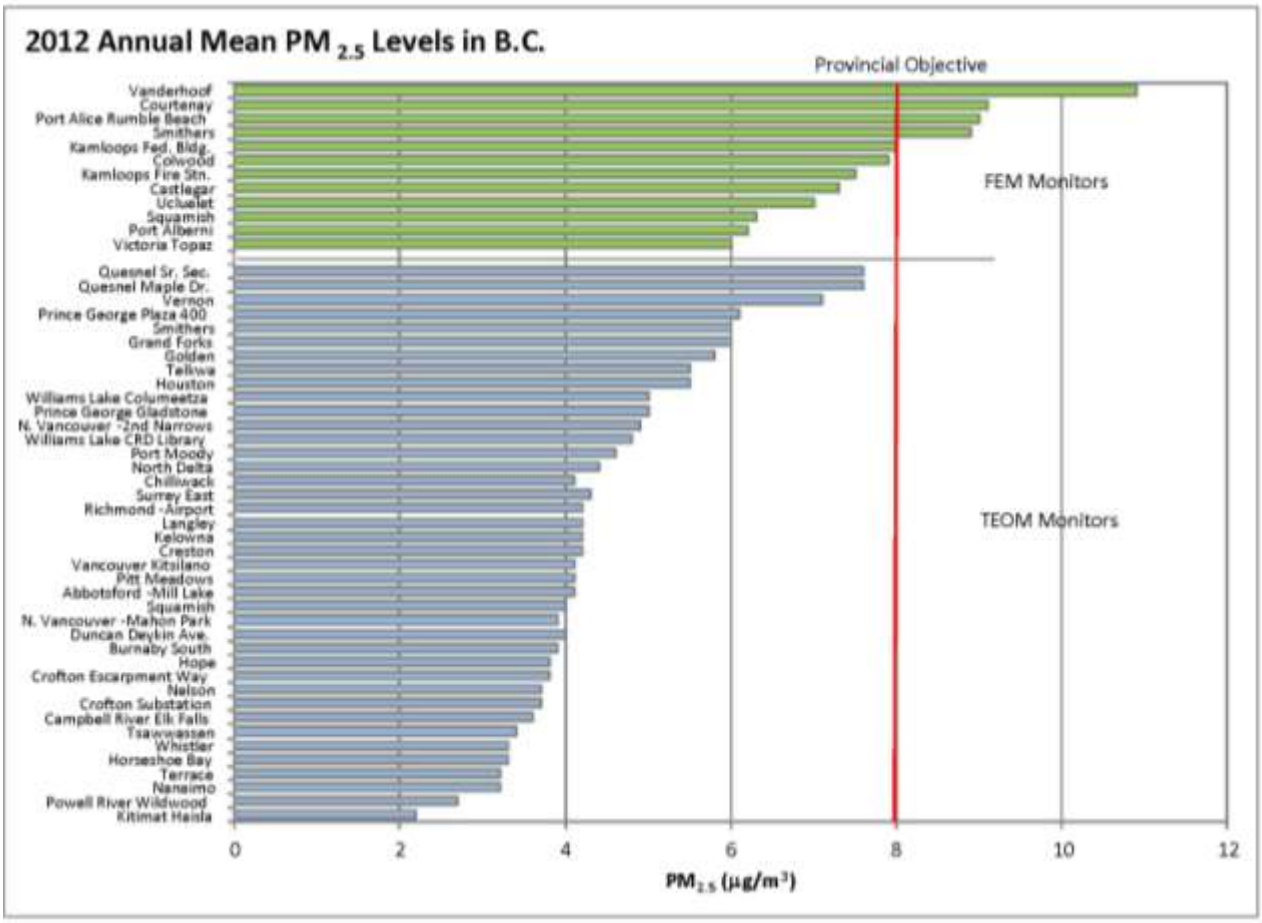

Figure 5: Summary of PM $_{2.5}$ levels in BC in 2012. Data from two sets of monitors are shown: from the older TEOM instruments (blue bars) and the new FEM instruments (green bars) (2013 State of the Air, BC Lung).

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While Campbell River's overall air quality ranks as "good", $PM_{2.5}$ pollution from residential wood burning may be higher in low-lying areas that are susceptible to inversions. These hot spots known locally as "Smoky Hollows" are important to address because pollutants are released right where people live and play (E. Plain, personal communication). Figure 6 shows seasonal $PM_{2.5}$ trends at the Dogwood ambient air quality monitoring station and how various burning sources contribute to overall concentrations. The graph also shows the time of year that Campbell River can take action to reduce and change poor wood-burning practices. Between 2006 and 2010, $PM_{2.5}$ concentrations were the highest in the winter months (December and January)

and are generally thought to be driven by residential wood heating, while fall burning[1] and wildfires were also noted to contribute to degraded air quality in Campbell River.

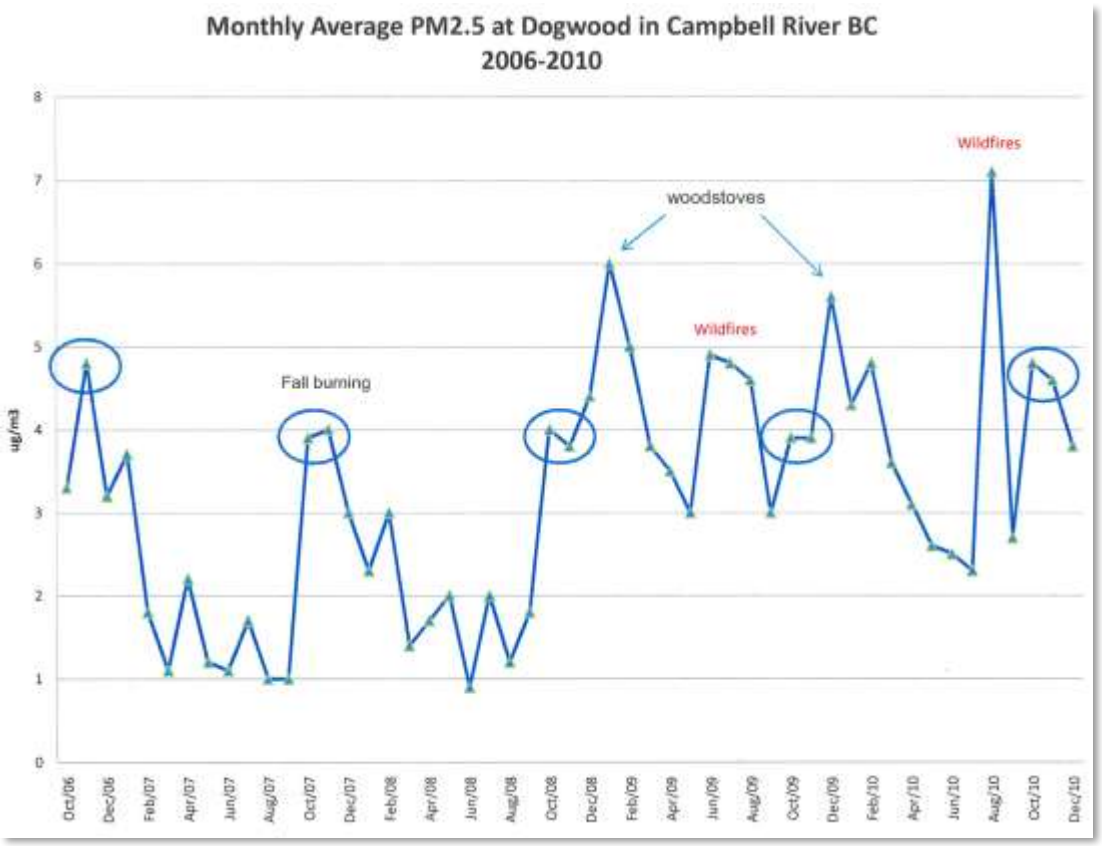

Figure 6: Fine particulate $PM_{2.5}$ concentrations recorded over a four-year period at Campbell River's Dogwood ambient air quality monitoring station (Plain, 2011).

3.2 Ozone and Nitrogen Dioxide

Ground-level ozone (O_3) and nitrogen dioxide (NO_2) are also measured at the Dogwood ambient air quality monitoring station. These contaminants are two components of urban smog and have similar human health and environmental effects as $PM_{2.5}$. The BC Lung Association State of the Air reports for British Columbia indicate that levels for these pollutants are well below national ambient air quality objectives and standards in

[1] In 2007, the City of Campbell River restricted open burning in most of the City through the Clean Air Bylaw. Recreational fires 60cm in diameter for the purpose of cooking food and the provision of heat are still permitted.

Campbell River. Ground level ozone is compared to the Canada wide standard[2] and nitrogen dioxide is compared to the national ambient air quality objective[3].

4 Air Quality Surveys

4.1 Survey Rationale

The City of Campbell River undertook a series of air quality surveys in 2010 and 2011. The goal of these surveys was to confirm and measure fine particulate pollution at reported hot spots throughout Campbell River where smoke from residential wood heating tends to settle and accumulate. Additionally, the City wanted to compare fine particulate pollution measurements from the hot spot areas with measurements recorded at the Dogwood ambient air quality monitoring station.

To do this the City used a nephelometer to conduct a series of mobile and stationary surveys. The nephelometer was loaned from the University of Victoria Spatial Sciences Lab. City staff along with other woodstove exchange program coordinators received training on how to set up and operate the equipment from Dr. Eleanor Setton, Adjunct Assistant Professor, Geography, University of Victoria Spatial Sciences Research Lab.

The survey information provides a brief snap shot of air quality measurements to flag potential issues and the results also assist the City of Campbell River with targeted woodstove exchange program air quality information.

4.2 What is a Nephelometer?

The type of nephelometer used in these surveys measures the back-scatter of light that results when fine particles are drawn through the light beam. The light intensity is measured at 'zero' using a clean gas such as CO_2 and then the relative difference can be measured from the zero when polluted air is drawn through the instrument. For example, a higher back scatter value indicates a higher concentration of fine particles ($PM_{2.5}$) in the air. Essentially a nephelometer "inhales" air samples and checks for $PM_{2.5}$.

[2] For more information see http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf .
[3] For more information see Environment Canada National Air Quality Objectives http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=24441DC4-1.

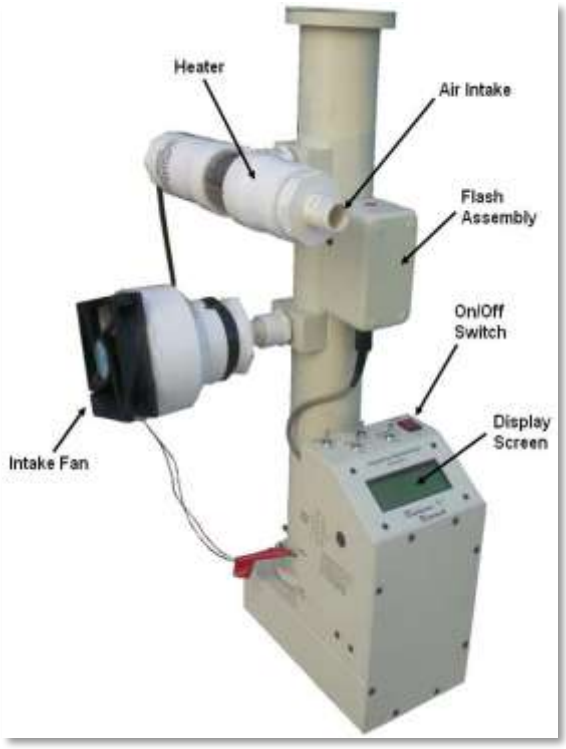

Figure 7: Nephelometer (Ministry of Environment, City of Nanaimo, 2010)

4.3 Mobile Nephelometer Surveys

4.3.1 Methods

Reported and known smoky locations were used as a basis for selecting the driving route for the mobile nephelometer surveys in the winter of 2010. A Radiance Research M903 nephelometer was operated from the backseat of a Toyota Hybrid car, with an intake tube extending from a slightly open window (Figures 8 and 9).

Figure 8: Nephelometer loaned from the University of Victoria Spatial Sciences Lab in 2010 and 2011.

Figure 9: Nephelometer positioned in vehicle.

The City's intent was to conduct the surveys on cold, clear evenings when wood smoke tends to accumulate and the surveys were run from January 22 to March 18, 2010 between the hours of 17:00 and 21:00. The route was driven in the same direction and had the same start and stop location each time (Appendix II details the driving route). The nephelometer was equipped with a fan for the intake of outside air and it was also fitted with a sample line heater to keep intake air at a constant temperature and humidity. An equation converts light scatter into $PM_{2.5}$ concentrations in micrograms per cubic metre: $PM_{2.5}$ ($\mu g/m^3$) = ((100,000 x light scatter value) – 0.01) / 0.28).

The nephelometer was set to log every 15 seconds on the 0, 15, 30, and 45 second marks of each minute. The GPS was set to log every second. After each run, the nephelometer data was downloaded in text format using the program HyperTerminal. The Garmin GPS data was downloaded and converted to text format using the Garmin program Mapsource. The nephelomter and GPS data was then imported into Microsoft Excel. The backscatter formula was applied and nephelometer and GPS data were matched by time.

Since the City was interested in the spatial distribution of $PM_{2.5}$ concentration over the study area, the nephelometer data was mapped out for each run using the geographic information system ArcMap. These maps were then analyzed for reoccurring hotspot patterns throughout the study.

4.3.2 Results: Data Summary

Table 1 shows the results from the six 2010 mobile nephelometer surveys. To view the map of each survey route with the nephelometer readings refer to Appendix III.

Table 1: Mobile Nephelometer 2010 Survey Results

Date (2010)	Time (hours)	Max $PM_{2.5}$ Level ($\mu g/m^3$)	Mean $PM_{2.5}$ Level ($\mu g/m^3$)	Standard Deviation ($\mu g/m^3$)	Max $PM_{2.5}$ Locations "Hotspots"
Jan-22	18:13 - 20:15	13	3.8	3.3	Northern and southern extent of the driven route in close proximity to the coast (Alder Street and 6th Avenue are recorded highs)
Jan-28	17:51 - 19:55	11	2.1	1.7	Southern extent of the driven route in Willow Point (along Holm Road)
Feb-7	17:40 - 19:44	12	3.4	2.3	Southern extent of the driven route in Willow Point (Holm Road)
Feb-20	18:08 - 20:06	19	3.9	3.3	Along Alder Street between 5th Avenue and 7th Avenue; along South Island Highway between Erickson Road and Hilchey Road
Mar-4	17:21 - 19:08	13	1.1	0.8	Campbellton at 15th Avenue and Spruce Street
Mar-18	17:45 - 19:43	4	0.3	0.06	Robron Road and Dogwood Street; Raven Crescent

During the study period at the Dogwood ambient air quality monitoring station, the highest recorded hourly concentrations of $PM_{2.5}$ were 25.0$\mu g/m^3$ on January 22, 2010 at 18:00 and 28.2$\mu g/m^3$ on February 20, 2010 at 20:00 (also see Table 2). This provides supporting evidence that wood smoke fine particulate values were likely elevated on those days as indicated during the driving surveys.

Table 2: 2010 hourly $PM_{2.5}$ levels measured at Dogwood ambient air quality monitoring station between 17:00-21:00 PST

Date; Time (2010; hours)	Hourly $PM_{2.5}$ ($\mu g/m^3$)	Date; Time (2010; hours)	Hourly $PM_{2.5}$ ($\mu g/m^3$)
Jan-22; 18:00	25	**Feb-20; 18:00**	9.6
Jan-22; 19:00	23.1	**Feb-20; 19:00**	26
Jan-22; 20:00	20.5	**Feb-20; 20:00**	28.2
Jan-22; 21:00	11.5	**Feb-20; 21:00**	24.8
Jan-28; 18:00	3.7	**Mar-4; 17:00**	5.3
Jan-28; 19:00	9.3	**Mar-4; 18:00**	6.1
Jan-28; 20:00	8	**Mar-4; 19:00**	5.8
Jan-28; 21:00	16.4	**Mar-4; 20:00**	8.1
Feb-7; 18:00	15.1	**Mar-18; 17:00**	0
Feb-7; 19:00	26.4	**Mar-18; 18:00**	1.7
Feb-7; 20:00	34.1	**Mar-18; 19:00**	11.3
Feb-7; 21:00	17.8	**Mar-18; 20:00**	16.5

The map in Figure 10 shows $PM_{2.5}$ hot spots (red lines) along the driven route identified in the six 2010 mobile nephelometer surveys. Hot spots were defined as those areas with fine particulate readings in the two highest particulate categories recorded over the surveys (7µg/m^3 or greater). Collectively, hot spots covered approximately 29% of the total driven route.

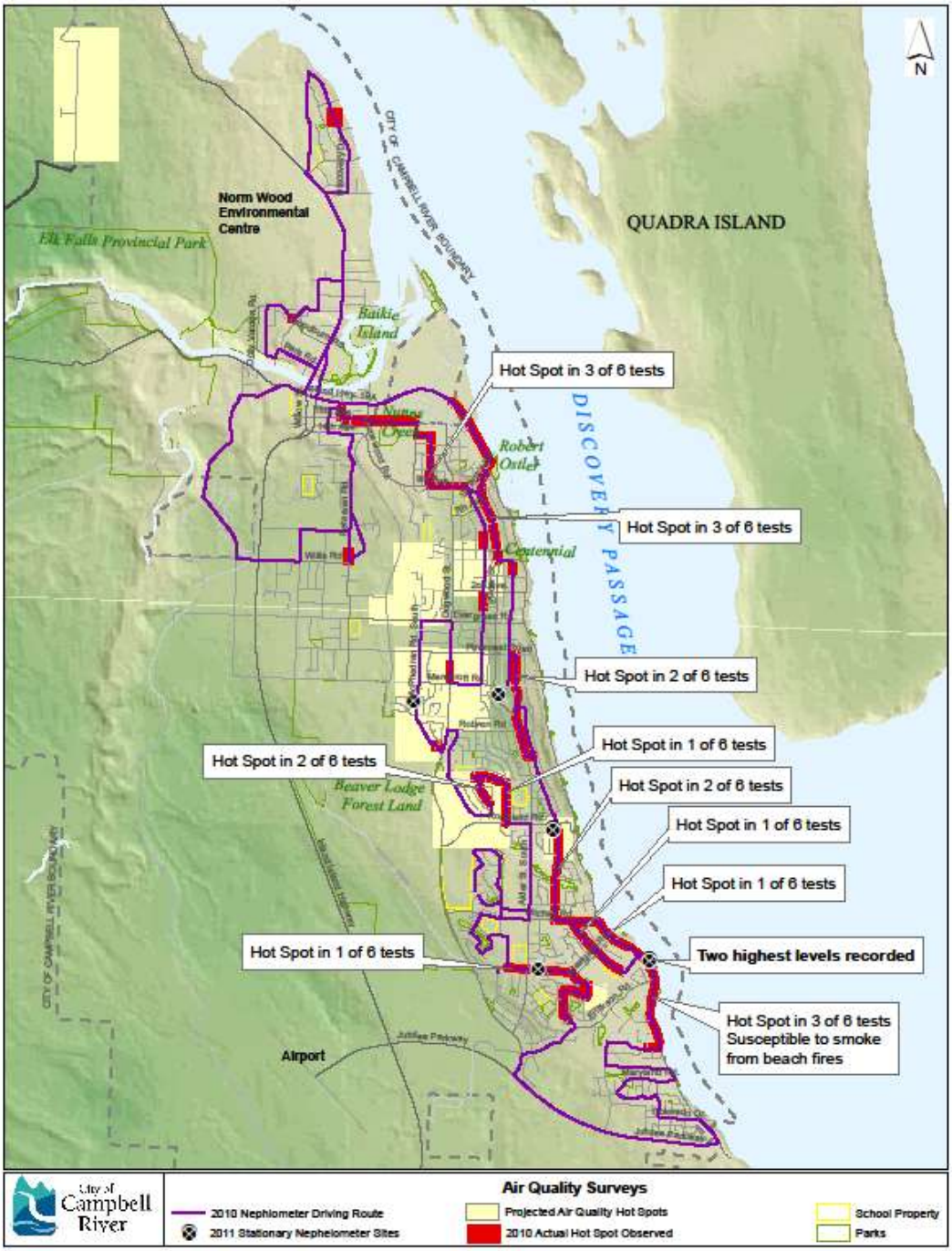

Figure 10: Compilation of six 2010 mobile nephelometer surveys and five 2011 stationary nephelometer surveys.

4.3.3 Results: Discussion

The mobile nephelometer surveys confirmed only a portion of the reported/suspected hot spot areas (shown in Figure 10 as the yellow shaded polygons). However, a number of additional hot spots were identified on the driving route including in the Campbellton area (west of Ostler Park and near Nunns Creek Park on the map) and the Willow Point area (at the south end of the map). The study also identified areas that have consistently low $PM_{2.5}$ concentrations. On the very northern and western part of the driven route where residential development is sparse the $PM_{2.5}$ values were the lowest, indicating less smoke accumulation.

The wood smoke hot spots located in the Willow Point area are most likely a result of residential wood heat smoke draining from the surrounding elevated regions which add to the locally generated smoke in the immediate area. A funnel effect takes place whereby in the evenings smoke slowly drains downhill through the sloped areas of land added by localized land-sea breezes. The topography is such that the hot spot along the Old Island Highway between Erickson and Hilchey roads is particularly susceptible, along with the contribution of wintertime beach fires, which was observed during several surveys.

Overall, a decrease in wood smoke pollution was recorded beginning in late February 2010 and continuing until the final survey day on March 18, 2010. January 22 and 28, and February 7 and 20, 2010 surveys all had $PM_{2.5}$ concentrations over $10\mu g/m^3$. Only one location on the driving route was above $10\mu g/m^3$ during the March 4 and 18, 2010 surveys. Decreasing smoke pollution was expected, with increasing temperatures and the end of the wood burning season. It also means the higher $PM_{2.5}$ concentrations experienced in the colder months can likely be attributed to wood smoke from home heating.

Hourly average readings from the Dogwood ambient air quality monitoring station were much higher compared to what the mobile nephelometer recorded reaffirming that the value of the driving surveys is to establish relative hot spots. For example, recordings on the January 22, 2010 survey did not record any $PM_{2.5}$ concentrations more than $13\mu g/m^3$; however, the Dogwood ambient air quality monitoring station measured between 11.5 and $25.0\mu g/m^3$ during the period of the survey. Similarly, the February 20, 2010 Dogwood ambient air quality monitoring station readings are between 9.6 and $28.2\mu g/m^3$, while the mobile nephelometer did not record any concentrations over $19\mu g/m^3$. The maximum hourly value recorded by the Dogwood ambient air quality monitoring station was $46\mu g/m^3$ on February 21, 2010 at midnight. This value is outside of the nephelometer survey time range and the high value reinforces that wood smoke pollution tends to build up over the evening hours.

It should be noted that the nephelometer readings are brief snapshots of the $PM_{2.5}$ concentration taken every 15 seconds along the driven route. The Dogwood ambient air quality monitoring station records $PM_{2.5}$ concentrations continuously at a single location and the readings represent an hourly average or 3600 seconds of data averaged into one reading. As the Dogwood ambient air quality monitoring station records continuously, the smokiest conditions are captured and concentrations could be higher

at times than what is captured by the mobile nephelometer. Also, since the mobile surveys were conducted fairly early in the evening when smoke levels were likely still building, the nephelometer would only have recorded the early-evening lower pollution levels. The overall low concentrations for Campbell River, despite the early evening time of the surveys, may not actually be far off from what they could read in the later evening due to the 2010 El Nino winter, which was much warmer than 2008/09 (E. Plain, personal communication, May 20, 2012).

Typically as the evening progresses, concentrations of $PM_{2.5}$ rise as woodstoves are in use (Dr. Eleanor Setton, email communication, July 2010). During the winter months between 2006 and 2008 Figure 11 shows that $PM_{2.5}$ concentrations as measured at the Dogwood Ambient Air Quality Monitoring Station rose in the early evening and reached maximum levels between 18:00 and 24:00. A lesser peak was recorded in the morning hours perhaps in response to rekindling or starting morning fires.

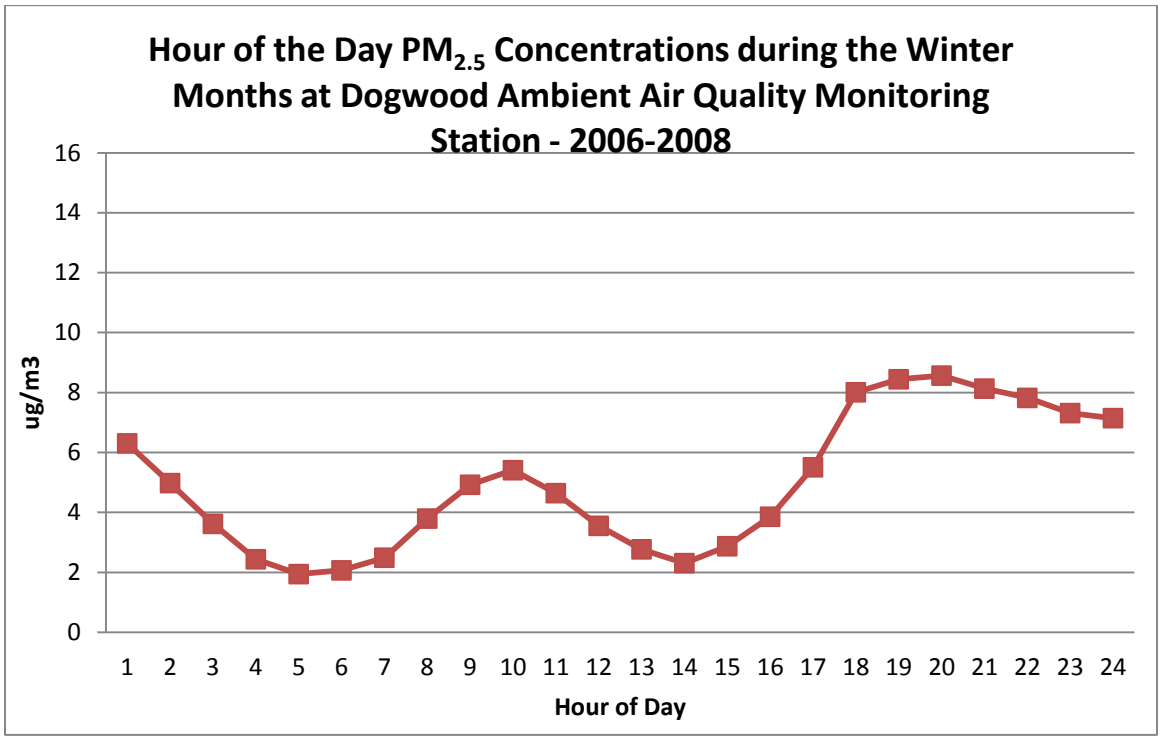

Figure 11: Diurnal chart of fine particulate matter concentrations from the Dogwood Ambient Air Quality Monitoring Station between 2006 and 2008 (Ministry of Environment 2012)

Similar trends have been observed in other areas. For example, in the Capital Regional District in 2007, $PM_{2.5}$ peaks occurred between 22:00 and 23:00 (CRD 2007). Similarly, in the Greater Victoria Regional District in 2010, concentrations occurred later, from 23:00 to 24:00 (CVRD 2010). The City of Nanaimo in 2009 recorded slightly earlier peaks in $PM_{2.5}$ between 18:00 and 20:00 (City of Nanaimo 2009).

With the hot spot areas largely pinpointed, stationary nephelometer surveys were conducted in 2011 to determine maximum daily pollution levels in a selection of Campbell River's hot spot areas.

4.4 Stationary Nephelometer Surveys

4.4.1 Methods

Five multiple-day stationary nephelometer surveys were conducted the following year; four occurred between February 17 and March 17, 2011 and one survey occurred in October 2011. Locations were chosen to reflect hot spots located from the mobile nephelometer surveys conducted in 2010, as well as a result of public air quality complaints. The locations of the stationary surveys are shown in Figure 10. Attempts were made to conduct these surveys during cold clear weather windows, but given the length of the surveys weather conditions were not always ideal with some rain and wind encountered. The survey length averaged 5.6 days with the shortest survey conducted over a four-day period and the longest survey conducted over an eight-day period.

The nephelometer was reprogrammed from logging every 15 seconds (used in mobile surveys) to every 15 minutes. After each survey, the nephelometer data was downloaded in text format using the program HyperTerminal and graphs were prepared using Excel.

4.4.2 Results: Data Summary

Table 3 shows 2011 maximum $PM_{2.5}$ levels recorded from the five stationary surveys. Figure 12 shows graphed results for one of the stationary nephelometer surveys with the poorest overall air quality. To see all five stationary survey results refer to Appendix IV.

Table 3: 2011 maximum $PM_{2.5}$ levels recorded during stationary surveys

Neighbourhood	Location of Nephelometer	Survey Date (2011)	Max $PM_{2.5}$ Level ($\mu g/m^3$)	Time Max $PM_{2.5}$ Level Recorded (hours)
Rockland	Edgewood Drive	Mar 10-14	40.5	7:00
Rockland	Leed Road	Feb 24-28	136	21:00
Rockland	South Alder Street	Mar 17-24	69	1:00
Willow Point	South Island Highway	Feb 17-20	350	16:00
Willow Point	Holm Road	Oct 12-17	320	17:00

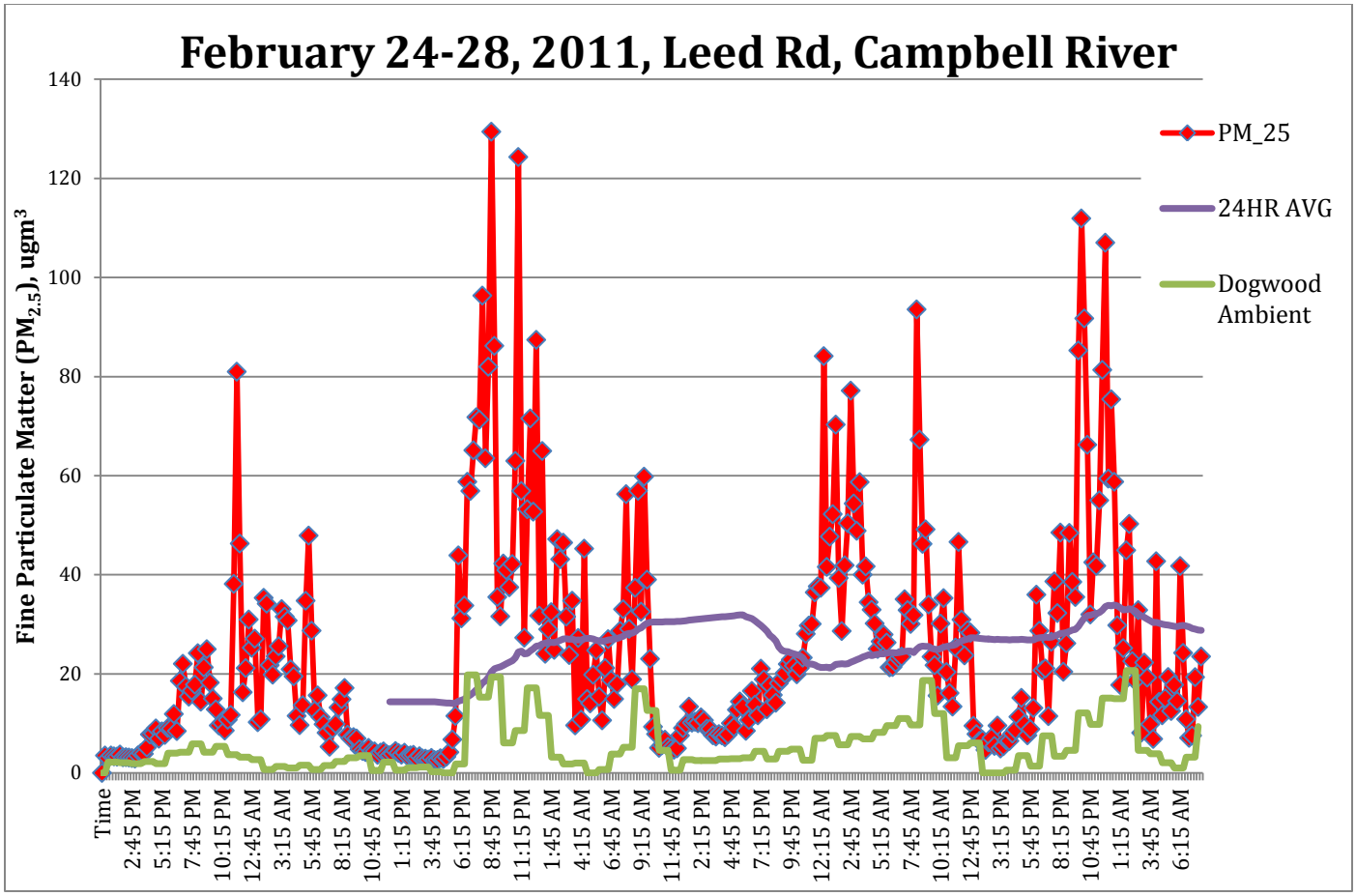

Figure 12: Graphed $PM_{2.5}$ results for 24-28 February, 2011 stationary nephelometer survey at Leed Rd, Campbell River (red line).

In Figure 12 above, the nephelometer $PM_{2.5}$ points (represented by the red line) are averaged every 15 minutes. $PM_{2.5}$ measurements exceeded 60µg/m3 on all four survey evenings and the 24-hour provincial ambient air quality objective of 25µg/m3 for fine particulate matter was also exceeded throughout most of the survey (rolling 24-hour average from stationary nephelometer survey is represented by the purple line). The Dogwood ambient air quality monitoring station data for this time period is represented by the green line.

4.4.3 Results: Discussion

The graphed results of the stationary surveys clearly showed a rise in fine particulate pollution over the evening hours at each location. Overall, the 2011 stationary surveys recorded much higher particulate values than the mobile surveys in 2010 and levels were also much higher than observed at the Dogwood ambient air quality monitoring station in 2010. The highest $PM_{2.5}$ levels recorded spiked to over 300µg/m^3 for short periods of time at the South Island Highway on February 17, 2011 and at the Holm Road location in October, 2011 in the Willow Point hot spot area. In some instances these extremely elevated fine particulate concentrations coincide with reported toxic smelling smoke in the neighbourhood (suspected burning of garbage).

Isolated spikes of fine particulate matter on the graphs are not cause for undue alarm since the short duration of a single spike represents a fleeting moment of pollution.

Similar spikes in poor air quality could occur around a smoky barbecue, burning food in the kitchen and even as a result of snuffing out a candle (Dr. Eleanor Setton, UVIC Spatial Sciences Research Lab). That said, research evidence tell us that over time, regular exposure to fine particulates can impact health, and there should always be concern if the spikes are related to the poor practice of burning garbage in the woodstove.

Consistently high readings of elevated particulate matter over a longer period of time are a different matter as this increases personal exposure. For example, the readings shown in Figure 12 exceeded the 24-hour provincial ambient air quality objective of 25µg/m^3 for most of the four-day survey period. This may be cause for concern if this trend is reflected over the burning season. Public education efforts are warranted as a preventative measure to improve air quality for the health of local citizens.

5 Air Quality Initiatives

5.1 Wood Smoke Programs and Initiatives

Efforts to improve air quality in relation to residential wood heating smoke pollution in Campbell River have included: creation of a Wood Burning Appliance Smoke Management Plan (1994), creation of an air quality tip line (2000) and the production and direct mail out of extensive educational material (2002 and 2003). Refer to Appendix V for a timeline of all City air quality initiatives.

The City does not have an accurate measure of the number of residences that rely on wood heat or the proportion that may be operating old, inefficient solid fuel burning appliances. Based on a 2012 province wide survey (Mustel Group), what we do know is that residential wood burning is likely here to stay. The study found that of the various reasons tested for why people burn wood in their homes, three stand out equally strong, with about six-in-ten people citing them as major reasons for their choice: reliability in event of power outages, a wood supply is readily available and wood is cheaper compared to other fuels.

To address other sources of fine particulate air pollution, the City banned the burning of yard waste and land clearing debris through the Clean Air Bylaw in 2007 and citizens are offered yard waste pick up for four months of the year to encourage bylaw compliance. The popular curbside yard waste collection program runs two months in the spring (April/May) and two months in the fall (October/November). This service is for single family and duplex residential units and also includes a free yard waste drop-off centre open year round (available for local residential users only).

Currently the City is not considering adding a sunset clause to the Clean Air Bylaw whereby possession and use of all non-certified woodstoves in Campbell River would be banned. This solution may be warranted in locations where air quality is far worse than in Campbell River. For example, the town of Golden, BC banned the installation of new wood stoves in 2006 after recording some of the worst pollution in the province. Houston, BC saw an even more severe bylaw requirement for all non-certified wood

stoves to be dismantled by 2010. The most recent bylaw on Vancouver Island that addresses wood stove smoke pollution is in Port Alberni, which was passed in June 2012. This new Bylaw prohibits the installation of non-emission certified wood-burning appliances (either indoors or out) and provides a sunset date for the removal of non-emissions certified appliances from the premises after May 31, 2013 at the time of sale or property transfer (E. Plain, personal communication, September 10, 2012). Even though communities make decisions regarding air quality bylaws, Dr. Charmaine Enns of Vancouver Island Health Authority notes, "Appropriate indoor wood burning can be an effective, affordable and reliable heat source; as gas and hydro costs increase, the option of an indoor woodstove becomes more important" (personal communication, September 9, 2012). For this reason, the City of Campbell River has chosen to focus on an incentive and education approach towards addressing air quality issues as related to wood smoke concerns.

5.2 Provincial Wood Stove Exchange Program

Building on previous wood smoke reducing programs in Campbell River, the City's Environmental Advisory Commission recommended participation in the Provincial Woodstove Exchange Program (PWEP). Funding was first secured in 2009 and an exchange program has occurred each spring from 2010 to 2013.

The PWEP funding allowed the City to run an incentive based rebate program with local retailers to encourage the exchange of older, smoky wood stoves with low-emission appliances including CSA/EPA-certified clean-burning wood stoves and inserts, pellet stoves and gas appliances.

Figure 13: Former Mayor Charlie Cornfield (right) and former Councillor Roy Grant (second from left) present the first two $250 Woodstove Exchange rebate cheques in the spring of 2010.

The key provincial messages of the PWEP are:

- Government is taking a proactive approach to improving air quality and fuel efficiency.
- Individual action addresses a collective problem, and government is helping to facilitate that action.
- Old appliance change out is one aspect of the provincial program; *Burn It Smart* workshops are essential, since even newer wood stoves must be operated properly to realize improved efficiency (examples include the use of appropriately seasoned wood and good burning practices to ensure complete combustion).

While Provincial legislation (*Environmental Management Act*) specifies that older inefficient models can no longer be sold in the wholesale or retail market in British Columbia, many uncertified appliances are still in operation. Certified appliances that have been approved by the Canadian Standards Association and Environmental Protection Agency are marked with a 'CSA/EPA Certification'. Woodstove appliances purchased previous to 1990 are considered uncertified and should be considered for an exchange.

Older appliances were not designed to minimize the amount of smoke emitted, and newer designs produce 70% less particle pollution indoors and out (United States Environmental Protection Agency, 2012). Figure 14 shows the relative emissions of fine particles emitted from various solid fuel burning domestic appliances.

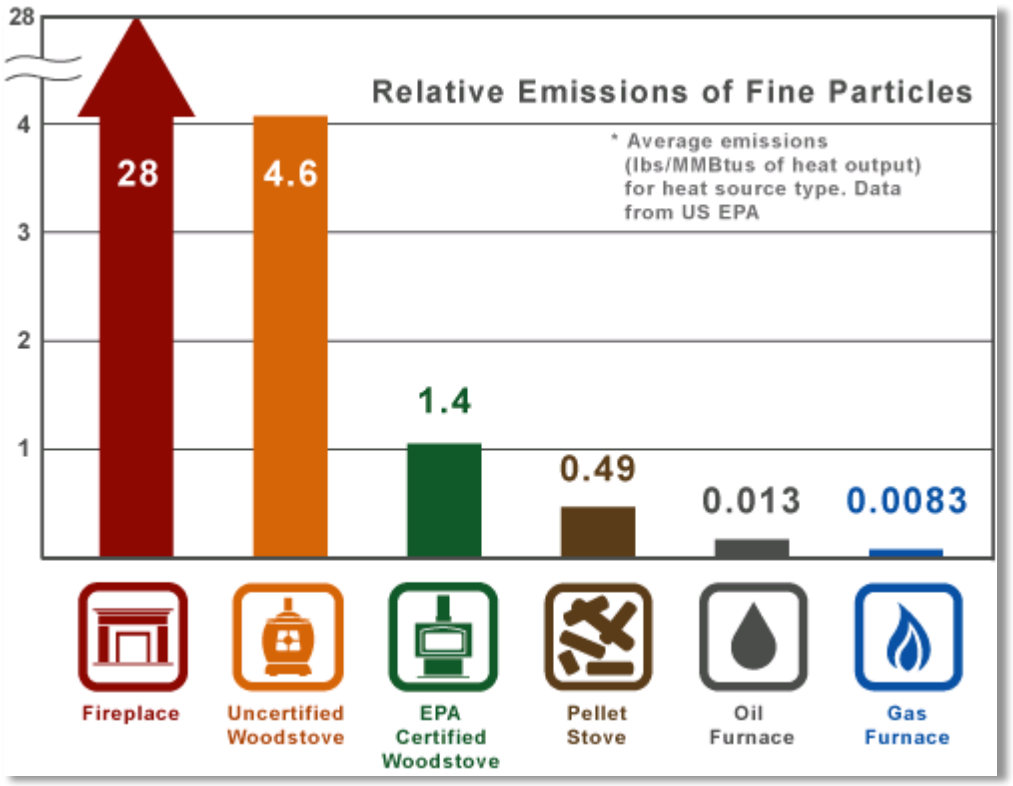

Figure 14: Relative Emissions of Fine Particles (United States Environmental Protection Agency, 2009).

5.3 Wood Stove Exchange Results – $PM_{2.5}$ Reductions

Between 2010 and 2013 Campbell River wood stove exchange programs, 150 old appliances were changed out in partnership with five local retailers (See Figure 15 for map of exchange locations). Table 4 shows emissions reductions resulting from the various exchanges with an overall total of 10,839.8 kg of $PM_{2.5}$ removed from Campbell River's airshed per burning season.

The average annual emission rate for all uncertified exchange appliances was set by BC MOE at 88.8 kg $PM_{2.5}$/yr; please see as per Appendix VI for more information concerning woodstove change-out emissions reduction estimates.

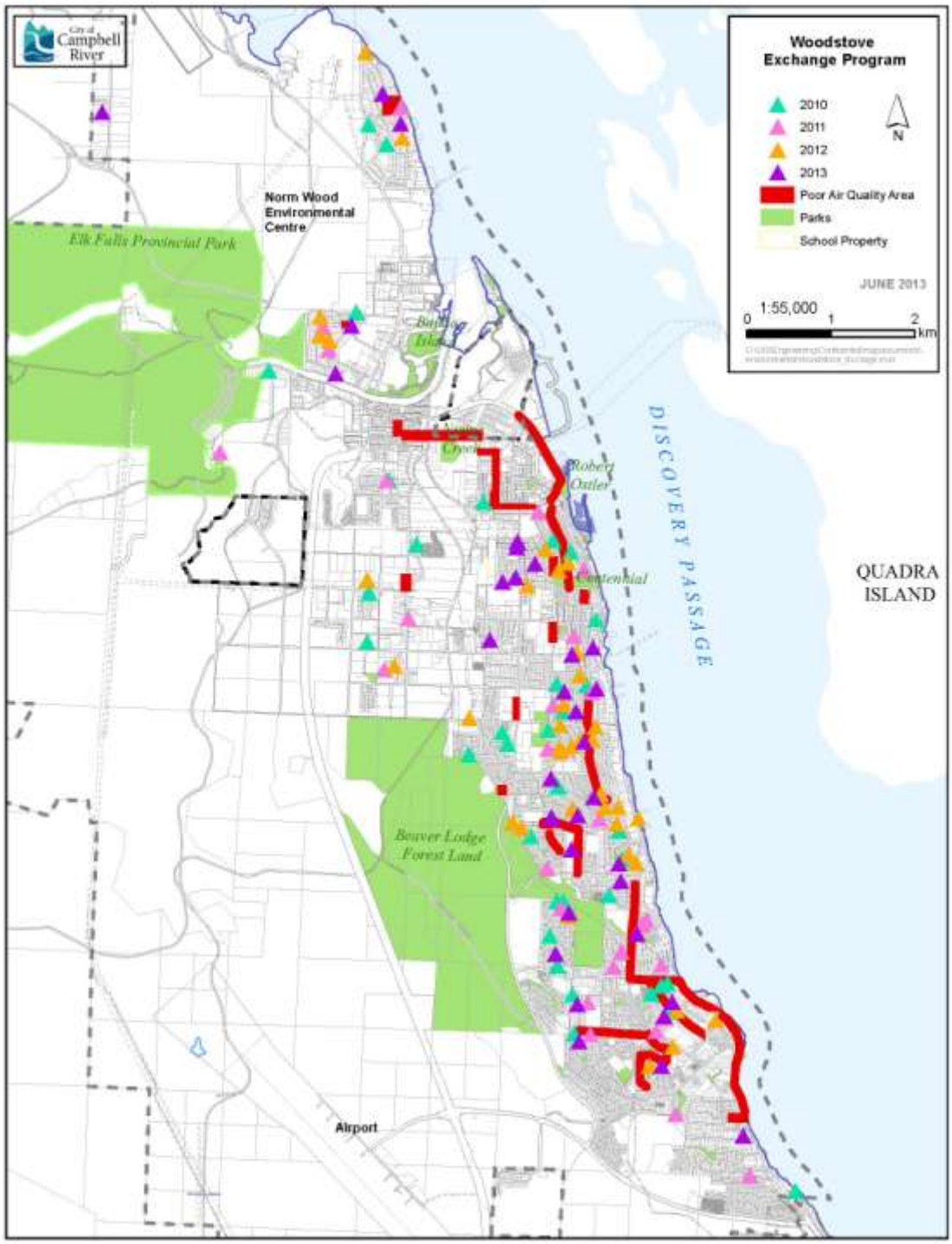

Figure 15: Map showing locations of the 150 woodstove exchanges over the 2010-2013 City of Campbell River Provincial Woodstove Exchange Program. The red lines on the map represent air quality hot spots recorded during the 2010 mobile air quality surveys.

Table 4: Emissions reductions from the Campbell River Provincial Woodstove Exchange Program 2010-2013

Uncertified Exchanged Appliance	New Replacement Appliance	Emissions Post Change-out per Appliance (kg/yr)	Total Emissions Reduction (kg/yr)
88 Conventional, wood stoves or inserts	71 EPA or CSA certified wood stoves or inserts	26.6	62.2 kg/yr per appliance = 4,416.2
	3 pellet stoves	9.8	79 kg/yr per appliance = 237
	13 natural gas appliances	0.2	88.6 kg/yr per appliance = 1,151.8
	1 electric appliance	0	88.8 kg/yr appliance = 88.8
62 Conventional fireplaces	20 EPA or CSA certified wood inserts	26.6	62.2 kg/yr per appliance = 1,244
	2 pellet inserts	9.8	79 kg/yr appliance = 158
	39 natural gas inserts	0.2	88.6 kg/yr appliance = 3,455.4
	1 propane insert	0.2	88.6 kg/yr appliance = 88.6
Overall Emissions Reduction			10,839.8 kg/yr

6 Summary of other Air Quality Initiatives

In addition to addressing woodstove smoke pollution through the City of Campbell River's participation in the Provincial Woodstove Exchange Program including air quality surveys, the City has a range of other initiatives that promote good air quality. These initiatives have been summarized below in Table 5. In the table the initiatives are linked to the BC Air Action Plan (June 2008).

Table 5: Air Quality Planning

BC Air Action Plan (2008)		City of Campbell River	
Action	**Item**	**Management Area**	**Target/Result**
#1	Make green transportation easy and attractive	Transportation (City of Campbell River, 2011)	1) Transit: • An additional bus was recently added to transit fleet for a total of ten buses that provide nearly 23,000 hours of annual service (7 days/week) • Ridership from 2010/11 to 2011/12 has increased 9% to over 605,000 rides/ year • Service includes connection to the Comox Valley transit system providing opportunities for commuters and North Island College students
			• Since Sept 2012, evening service offered 6 days a week
			2) Walkability: • 25 km Greenways Loop which goes around the perimeter of Campbell River almost complete • 800 lineal metres of infill sidewalks in residential neighbourhoods added annually to encourage and promote walking as an alternative mode of transportation
			3) Cycling: • 1.2 km trail added in 2012 to Simms Creek bike path • Increase in signage indicating bike routes • Fifth annual 2012 Bike To Work Week in Campbell River saw 107 teams registered and the number of riders jumped 12% from 2011

#4	Building a province-wide anti-idling movement	Idle Free Initiatives	Corporate anti-idling policy established and vetted through the City's Corporate Green Team Built on corporate and community Idle Free programming in partnership with School District 72: • Idle Free outreach conducted by City Bylaw officers adjacent to schools • Idle Free prompts (key fobs and decals) distributed at three community events in 2011 • Idle Free tips published in the Campbell River Courier Islander 2011 spring Live Green Guide • 4 Idle Free signs posted at City facilities • Idle Free signs now posted by the School District at all 14 area schools
#6	Retro-fit Transit buses	Transportation	• Most of the transit buses in Campbell River's system are between 13 and 15 years of age and have recently gone through a major overhaul process to extend their life to at least 18 years of service • BC Transit is looking at the cost/benefits or retrofitting vs. replacing its current bus fleet at a certain age. As technology improves, so does efficiencies of those vehicles. With the retrofits, there are some improvements in the efficiency, but not as much as would be achieved with fleets <12 years of age
#9	Get big diesels to stop idling	Idle Free Initiatives	Refer to Action #4
#10	Green vehicle fleets	Transportation	6 hybrid vehicles were purchased in 2010 for the City fleet
#12	BC Buys Green	Corporate Purchasing	City of Campbell River has incorporated an Environmental Evaluation section in the tender process (for example, International Standards Organization (ISO), Green Seal, Environmental Choice and Energy Star Certification)
#22	Get involved in airshed planning	2012 Air Quality Report	In addition to displays and workshops showcasing the air quality survey results in recent years, this report provides the community with analysis of air quality survey results in Campbell River completed as part of the Provincial Woodstove Exchange Program
#23	Make airshed planning part of community planning	Urban Forest Management Plan	The City has partnered with Greenways Land Trust to complete an inventory of the urban forest – this is Phase I of an Urban Forest Management Plan. In addition to determining the character and extent of the urban forest (canopy cover), results include: • Each hectare of urban forest produces enough oxygen to supply 45 people everyday • 20,197 tonnes of carbon are captured every year by the City's

			urban forest • Streets lined with trees show a 60% reduction in street level particulate readings The inventory forms the necessary research to inform a management plan to maintain the urban forest
		Land Use Planning	Ensure long-range plans (SOCP, Master Transportation Plan and Urban Forest Management Plan) align with air quality objectives
		BC Climate Action Charter	Campbell River signed onto the BC Climate Action Charter in 2007 committing to carbon neutrality in corporate operations by the end of 2012, measuring and reporting on corporate and community greenhouse gas (GHG) emissions, and creating complete, compact, energy efficient communities: • Adopted Carbon Neutral Plan in 2011 establishing GHG reduction targets • Corporate GHG emissions have been reduced by 12.5% from 2008 levels through building and utility retrofits including lighting, HVAC upgrades, solar hot water installations, City Hall green roof, fleet upgrades and right sizing, 5% biodiesel etc. • Carbon neutral reserve fund established • In partnership with other agencies (such as the Pembina Institute) the City supports and promotes senior agencies efficiency programs such as Live Smart and ecoENERGY
#25	Tighten burning regulations	Municipal Bylaws	Clean Air Bylaw: • Established in 2007, the bylaw restricts open burning (residential fires allowed) • Amended in 2009 to require that all new solid fuel burning appliances are certified to the Canadian or US standard • Restricts the burning of garbage and noxious materials in all circumstances Fire Services Bylaw: • Requires residents to have a permit upon installation of a solid fuel burning appliance • City permit must be submitted in order to receive rebate through the City's provincial woodstove exchange program Public Nuisance Bylaw: • This bylaw is currently under review and a new clause covering the emission of smoke and fumes is under consideration
#24	Get rid of smoky old woodstoves	Provincial Woodstove Exchange Program	• Over the period 2010-2013 150 woodstove exchanges have been completed in partnership with five local retailers (Figure 15) • Three seasons of *Burn It Smart* education and awareness programming has been completed including media releases, workshops, event displays, advertisements and forums • 2010 and 2011 air quality surveys conducted to help target information and awareness campaigns around air quality and to

			encourage residents to swap out old appliances

7 Conclusion and Recommendations

This report provides a resource for residents of Campbell River to become aware of wood smoke related air quality issues and solutions. While Campbell River's air quality ranks among the best in British Columbia, stationary nephelometer surveys indicate that fine particulate wood smoke pollution may exceed the 24-hour provincial ambient air quality objectives during certain weather conditions in hot spot areas. This information supports the City's continued participation in the Provincial Woodstove Exchange Program to encourage the exchange of old inefficient appliances for clean burning units and to continue with *Burn It Smart* education. Nephelometer results to date also support additional stationary surveys given that the sample survey size has been small.

In planning for the health of Campbell River's airshed, it is important that the City continues to meet both provincial ambient air quality objectives for fine $PM_{2.5}$. Establishing a community-wide goal of meeting the provincial ambient air quality objectives for fine particulate matter (25µg/m^3 24-hour average and 8µg/m^3 annual average) is overall a good target. The City has been achieving these targets already at the ambient air quality station on Dogwood Street. Campbell River has a number of years of data available to examine trends at the monitoring site, which the public can also view online (http://envistaweb.env.gov.bc.ca/).

It should be Campbell River's goal to also meet these targets throughout hotspot areas. Determining if these latter targets are achieved could only be determined through periodic measurement with a nephelometer. A recommended measuring target of 3-year intervals (subject to nephelometer availability) could provide beneficial information that would supplement findings at the Dogwood ambient air quality monitoring station. If nephelometer surveys measurements indicate that air quality objectives are not being met in hot spot areas, additional efforts such as door to door outreach at these locations may be warranted.

To date, the swapping of old uncertified woodstoves has been a success. After four years of exchanges the program runs smoothly and a target of 35-40 exchanges each spring is achievable. As long as the province runs the program, the City should participate.

The City has found that *Burn It Smart* education and awareness programming is a much more difficult sell. Encouraging participation has been a challenge despite prizes (even prizes of significant value), advertising, retailer support, expert presenters and a variety of presentation techniques. Those who do attend are often the best burners in the community and those least in need of the information offered. During events where the City displayed air quality and wood stove exchange information, the results from the air quality surveys seemed to pique community interest the most.

In 2013, the City launched a Master Burner Program as part of the Provincial Woodstove Exchange Program to provide hands on education and one-on-one assistance with wood smoke issues. In addition to the educational component, participants were provided

with a range of free tools provided by the province to improve burning practices such as moisture metres, wood carriers, and wood storage kits. The 12 available spaces filled quickly and an extensive waiting list was generated. Building on the Master Burner approach is recommended for future programming.

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Appendix I – Provincial Woodstove Exchange Program Team

Burn It Smart / Master Burner program educators and coordinator(s):

Patty Rose, contractor
Kathleen Roberts, contractor
Kevin McCurrie, Guardian Chimney Services
Lyle Johnson, Clean Sweep Chimneys
Julie Stewart, Quality Stoves & Fireplaces Ltd

City of Campbell River staff:

Amber Zirnhelt, Sustainability Manager
Terri Martin, Environmental Coordinator
Amanda Taylor, Co-op student (summary of existing recent air quality monitoring efforts and *Burn It Smart* awareness programming, liaison with retailers and exchange participants)
Nina Baksh, Senior GIS Analyst (air quality monitoring and mapping)
Eve Flager, GIS Technician (map assistance)
Neil Borecky, GIS Analyst (nephelometer data management and graphing)
Julie Douglas, Communications Advisor (communications and media support)
Toni Falk, Clerk Technician (administrative support such as promotional materials, advertising and layout)
Pam Auld, Administrative Assistant I (voucher and rebate support)
Roy Smith-retired and Karl Read Bylaw Enforcement Officers (Clean Air Bylaw compliance)
Ross Squire-retired and Seth Hildebrand, Fire Prevention Officers (*Burn it Smart* workshops, inspections, Fire Services Bylaw compliance and permitting)

Program Partners

Participating Retailers:

Quality Stoves & Fireplaces Ltd
Bennett Sheet Metal & Heating Ltd
Just Gad Ltd/Just Wood Stoves
Guardian Chimney Services
Comox Fireplace and Patio

All of the local retailers have been fully supportive of the wood stove exchange program to date and their contributions are expected to continue including: arranging for additional manufacturer discounts, customer support with the rebate and voucher system, advertising, supply of door prizes, *Burn It Smart* workshop venues and expertise, and old appliance decommission and recycling.

Vancouver Island Health Authority (VIHA):

Charmaine Enns, Medical Health Officer for the North Island has helped to interpret previous air quality monitoring results and impacts to human health. Charmaine also participated on the air quality expert panel discussion in 2012. We will continue to call on VIHA for their expert advice.

Ministry of Environment:

In a similar fashion to VIHA, Earle Plain, Air Quality Meteorologist for the Coast Region has been an important advisor to the project. In addition to helping to interpret the air quality monitoring results he has also assembled and compared the data to the ambient air quality monitoring data in Campbell River. Earle also was the special guest speaker at the final education and awareness presentation in 2011 and participated on the air quality expert panel discussion in 2012. City of Campbell River will continue to draw on Earle's expertise.

University of Victoria, Spatial Sciences Research Lab:

Dr Eleanor Setton, adjunct assistant geography professor with a specialization in environmental exposures has provided important assistance with air quality surveys, nephelometer training and with the interpretation of results. Although the nephelometer on loan will be moving to another community in 2012, City of Campbell River will require Dr. Setton's expertise during the compilation of the air quality results to date.

Media:

Local media (two newspapers and two radio stations) have been very supportive of the program to date. Every City media release issued has been published and followed up with radio interviews. Air quality and wood burning have the attention of the community and a continued media relationship is expected.

School District 72 Green Teams:

The City and SD 72 Green Teams have been working cooperatively on a variety of events, policies and special projects including air quality.

Appendix II – Air Quality Survey Route

2010 Air Quality Survey Route - Campbell River Woodstove Exchange Program
Suggested start time 6:00pm: route takes approximately 2 hrs to complete.

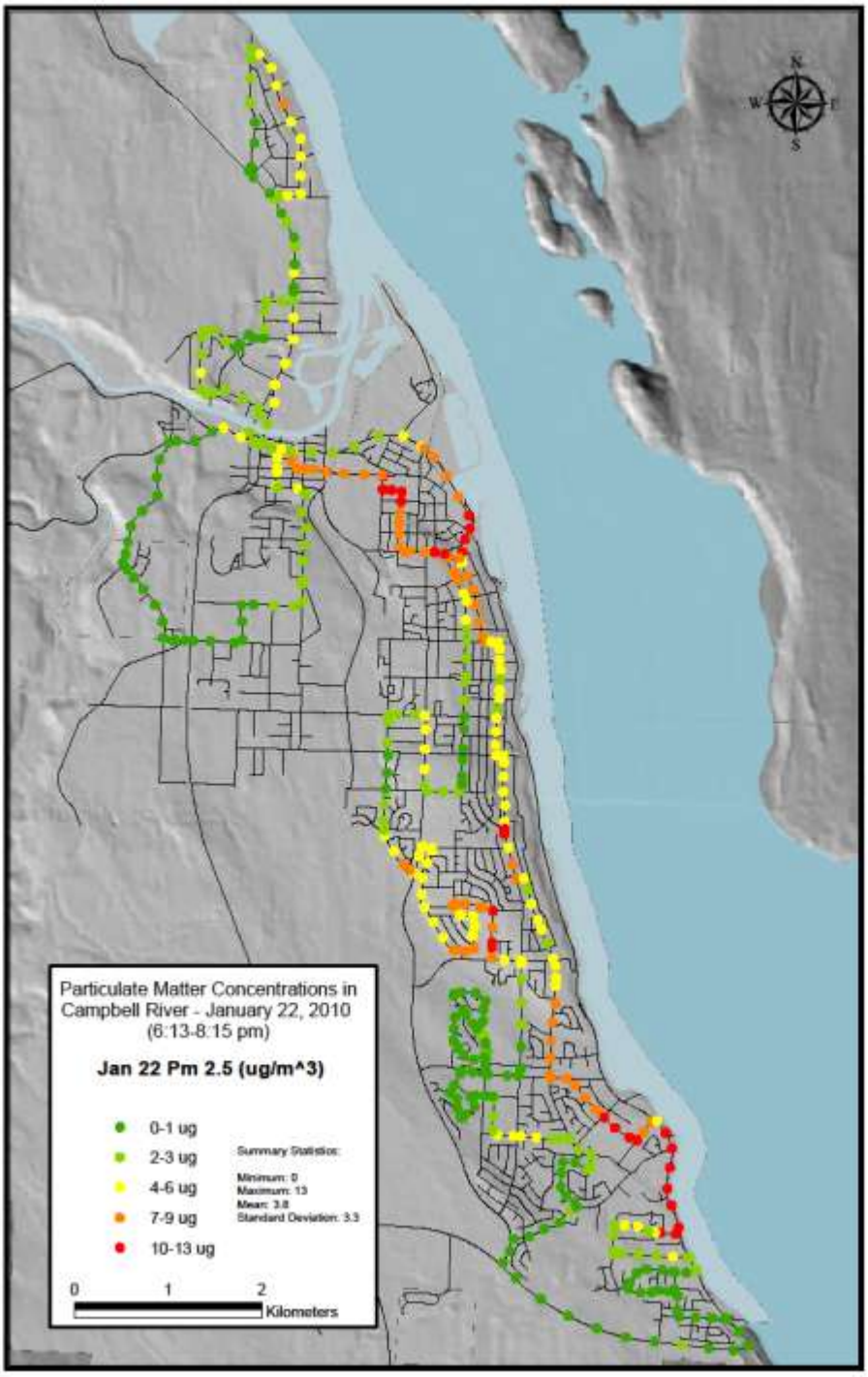
1	**Start at City Hall parking lot**
2	Turn S (right) on Alder St
3	Left (E) on 4th Ave
4	Right (S) on Thulin St
5	Left (E) on Pinecrest Rd
6	Right (S) on S Murphy St
7	Left (E) on Lal Rd
8	Continue Right (S) on Galerno Rd
9	Left (E) on Hilchey Rd
10	Right (S) on Eardley Rd
11	Left (N) on Larwood Rd
12	Right (S) on Island Hwy 19A
13	Right (W) on Dahl Rd
14	Left (S) on Willow Creek Rd
15	Left (E) on Twillingate Rd
16	Right (S) on Island Hwy 19A
17	Right (W) on Maryland Rd
18	Left (E) on Virginia Dr
19	Stay right (E) on Oregon Rd
20	Right (S) on Montana Dr
21	Left (E) on Colorado Dr
22	Right (S) on Island Hwy 19A
23	Right (W) on Jubilee Parkway

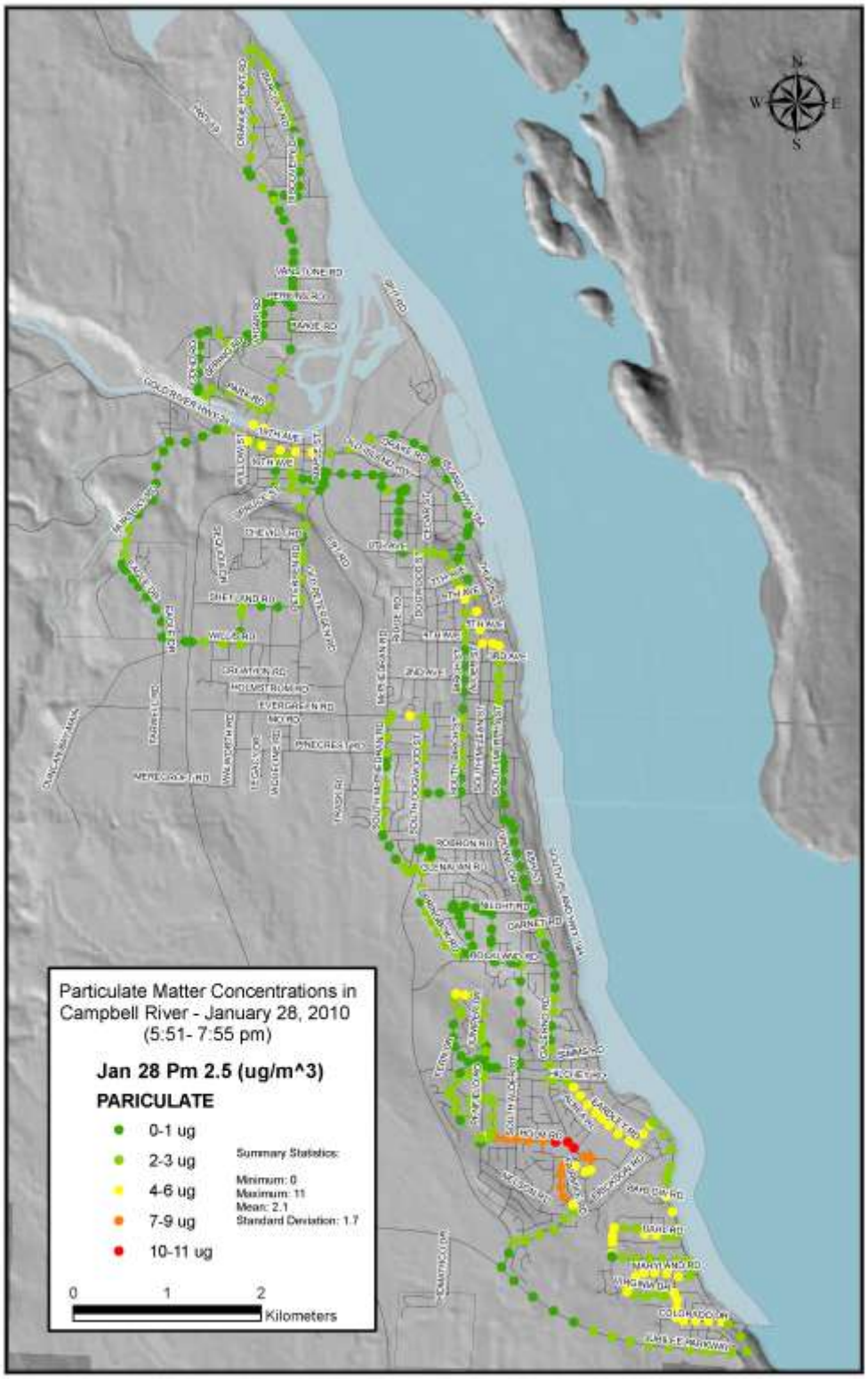
24	Right (N) on South Dogwood St
25	Right (E) on Erickson Rd
26	Left (N) on Fairmile Rd
27	Right (E) on Grayson Rd
28	Left (N) on Solderholm Rd
29	Left (W) on Harrogate Rd
30	Left (W) on Holm Rd & cross over S Alder
31	Right (N) on Milford Rd
32	Left (W) on Goodwin Rd
33	Left (S) on Joanne Dr
34	Right (NW) on Holm Rd
35	Right (N) on Varsity Dr
36	Right (N) on College Dr
37	Right (E) on Hilchey Rd
38	Left (N) on Penfield Rd
39	Left (W) on Meadowbrook Dr
40	Left (NW) on Penfield Dr
41	Right (E) on Juniper Dr
42	Left (S) on Penfield Rd
43	Left (E) on Parkway Rd
44	Left (S) on South Alder St
44	Left (W) on Rockland Rd
45	Right (N) on Shellbourne Blvd
46	Left (W) on Niluht Dr
47	Left (S) on Superior Dr
48	Left S) on Eland Dr

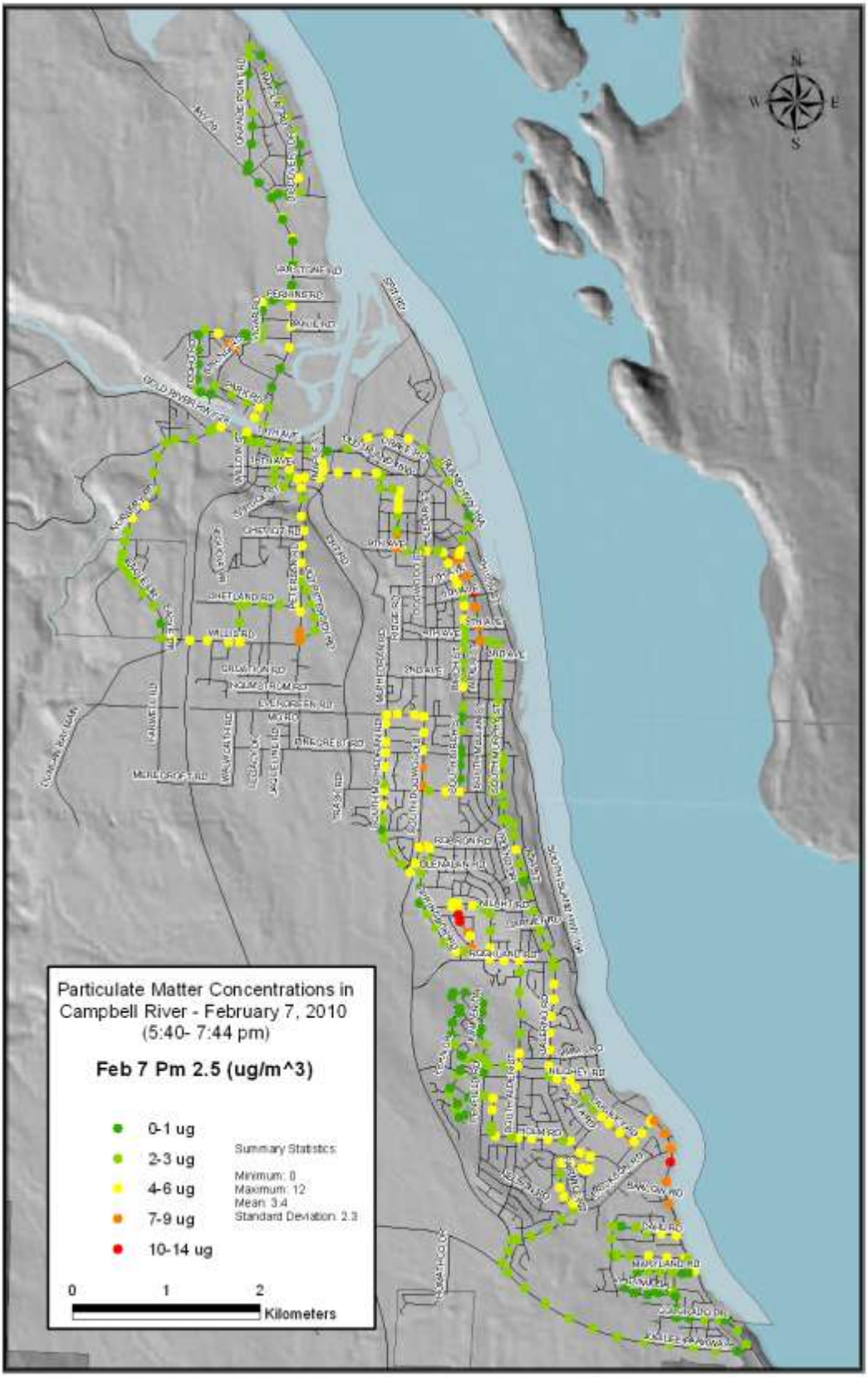
49	Continue left (S) on Springbok East
50	Continue curve W on Springbok Rd
51	Left (W) on Robron Rd
52	Left (S) on South Dogwood St
53	Right (NW) on South McPhedran Rd
54	Right (E) on Evergreen Rd
55	Right (S) on Dogwood St
56	Left (E) on Merecroft Rd
57	Left (N) on South Birch St
58	Left (W) on 9th Ave
59	Right (N) on Greenwood St
60	Left (W) on 14th Ave
61	Right (N) on Ironwood St
62	Left (W) on 16th Ave
63	Left (S) on Maple St
64	Right (W) on 15th Ave
65	Right (N) on Redwood St
66	Left (W) on 17th Ave
67	Left (S) on Spruce St
68	Left (E) on 14th Ave
69	Right (S) on Petersen Rd
70	Left (SE) on Old Petersen Rd
71	Right (N) on Petersen Rd
72	Left (W) on Shetland Rd
73	Left (S) on Walworth Rd
74	Right (W) on Willis Rd & cross over Inland Island Hwy

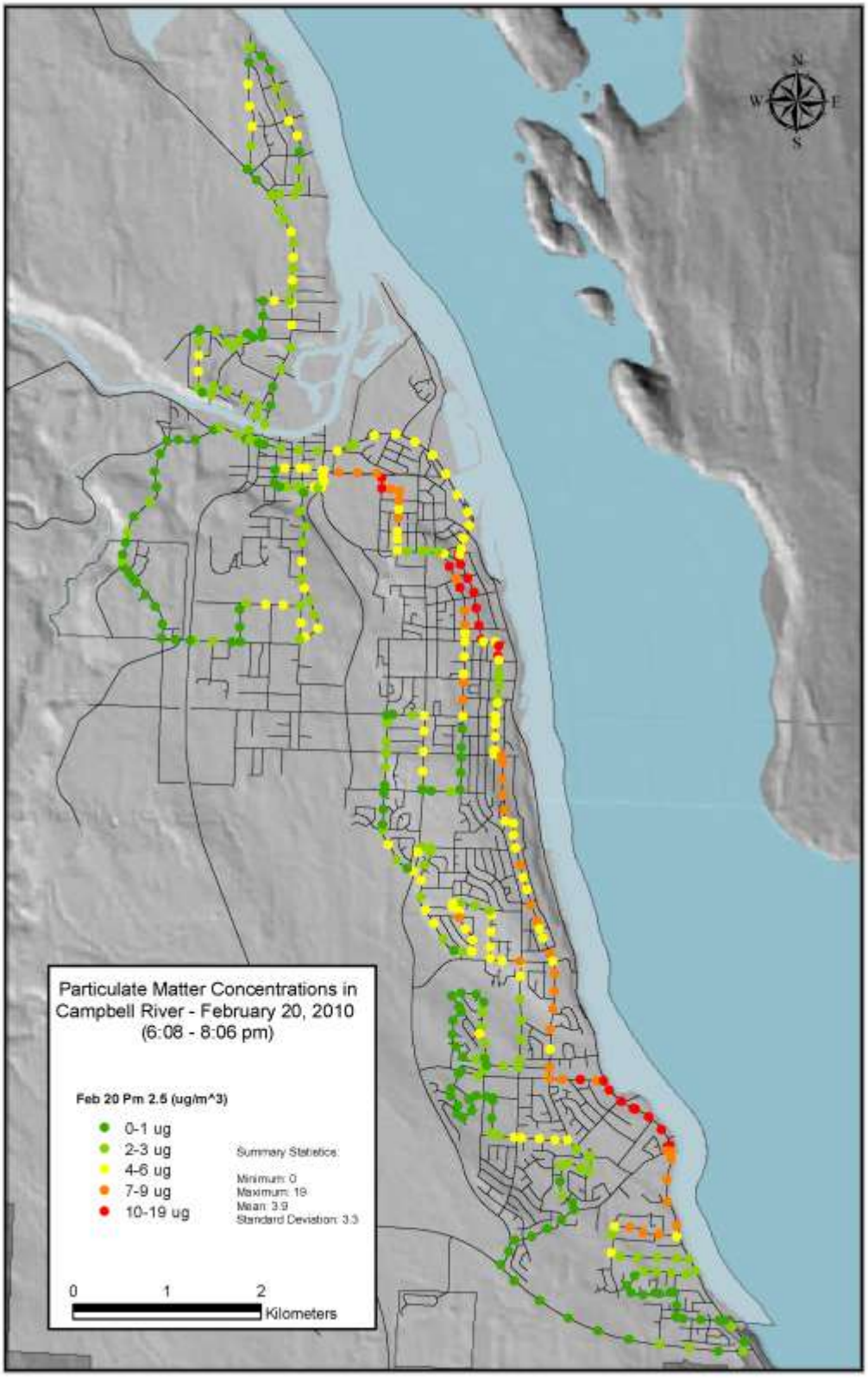
75	Right (N) on Eagle Dr
76	Right (NE) on Nursery Rd
77	Right (NE) on Quinsam Rd
78	Right (E) on Campbell River Rd (Hwy 28)
79	Left (N) on Tamarac St (Hwy 19)
80	Right (E) on McDonald Rd
81	Left (N) on Discovery Dr
82	Left (S) on Orange Point Rd
83	Left (SE) on Island Hw 19
84	Right (W) on Perkins Rd
85	Left (S) on Vigar Rd
86	Right (W) on Meredith Rd
87	Left (SW) on Vargo Rd
88	Right (NW) on Woodburn Rd
89	Left (S) on Coho Rd
90	Left (E) on Steelhead Rd
91	Left (NE) on Park Rd
92	Right (S) on Hwy 19
93	Left (E) on Campbell River Rd (which turns into Hwy 19A)
94	Return to Alder St City Hall parking lot

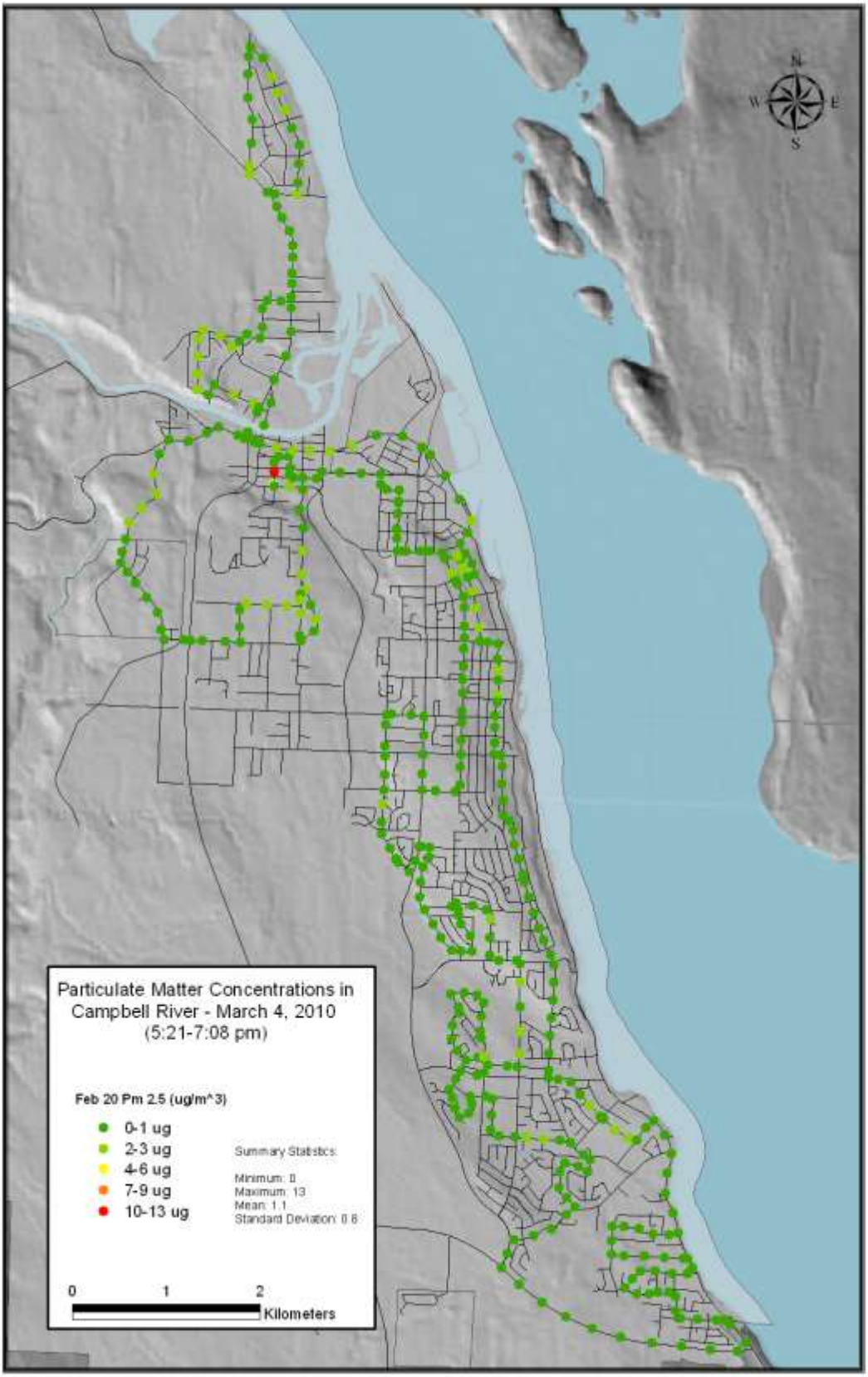
Appendix III – 2010 Mobile Nephelometer Survey Maps

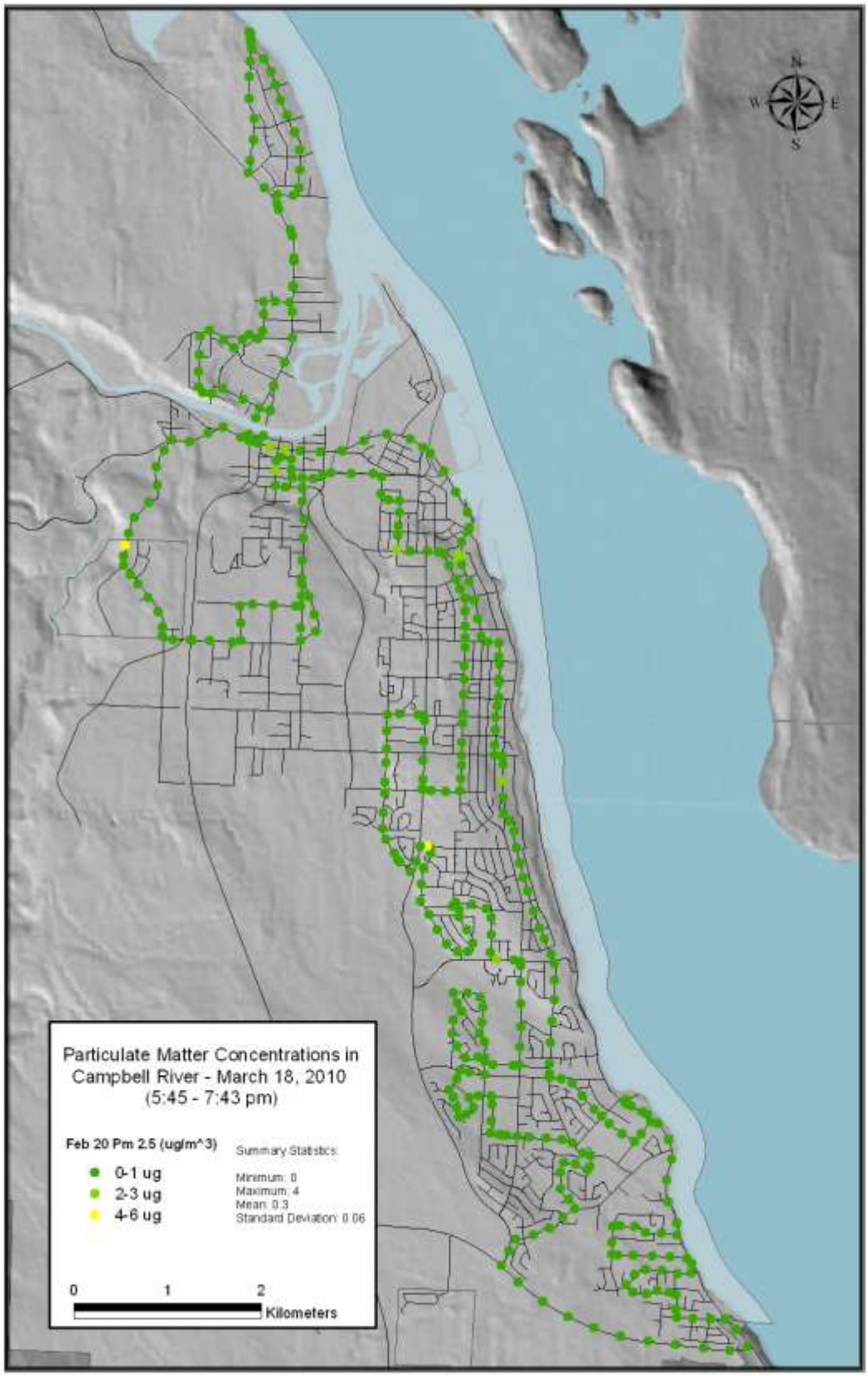



Particulate Matter Concentrations in Campbell River - January 28, 2010 (5:51- 7:55 pm)
Jan 28 Pm 2.5 (ug/m^3)
PARICULATE
0-1 ug
2-3 ug
4-6 ug
7-9 ug
10-11 ug
Summary Statistics:
Minimum: 0
Maximum: 11
Mean: 2.1
Standard Deviation: 1.7
0
1
2
Kilometers
N
W
E
S

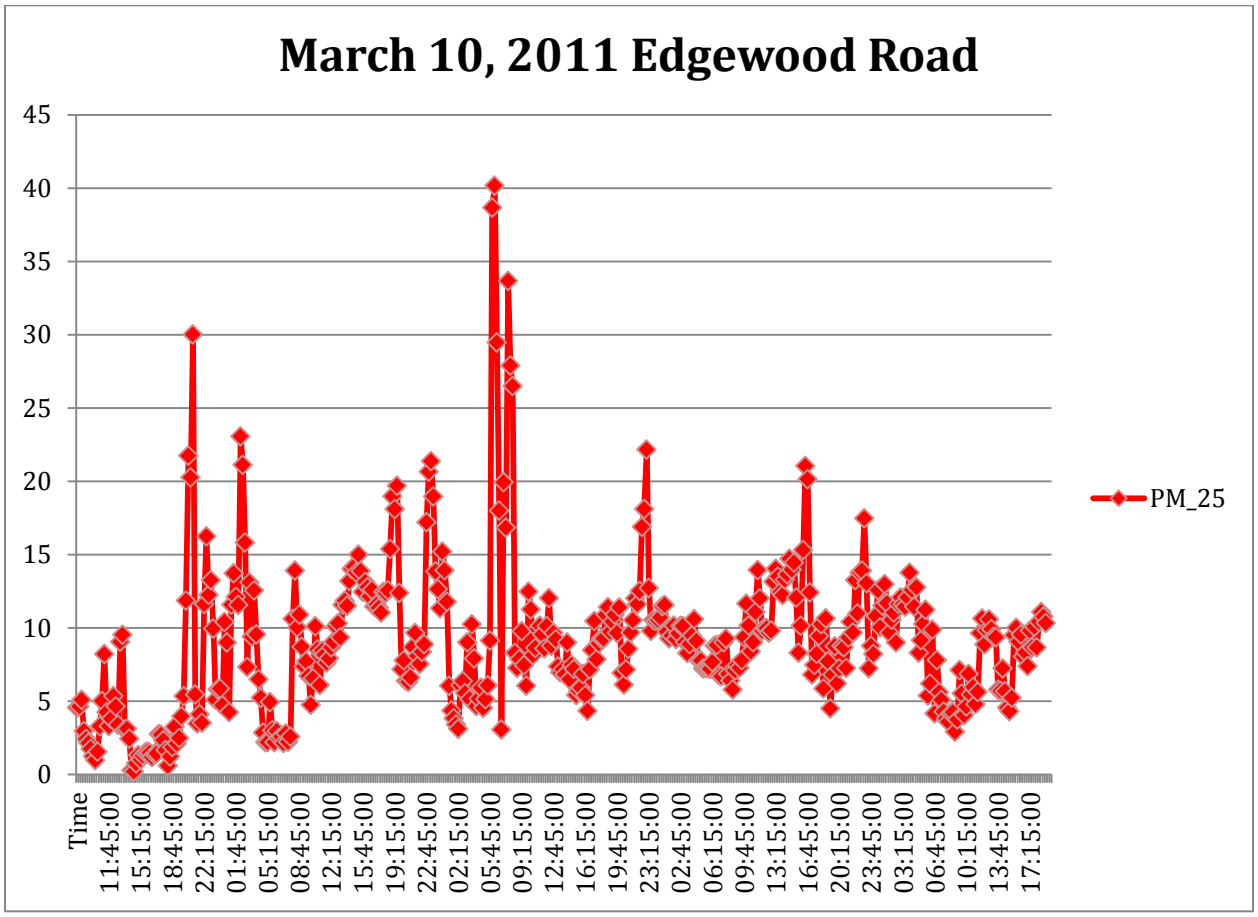

Particulate Matter Concentrations in Campbell River - February 7, 2010 (5:40- 7:44 pm)
Feb 7 Pm 2.5 (ug/m^3)
0-1 ug
2-3 ug
4-6 ug
7-9 ug
10-14 ug
Summary Statistics:
Minimum: 0
Maximum: 12
Mean: 3.4
Standard Deviation: 2.3
0
1
2
Kilometers
N
W
E
S

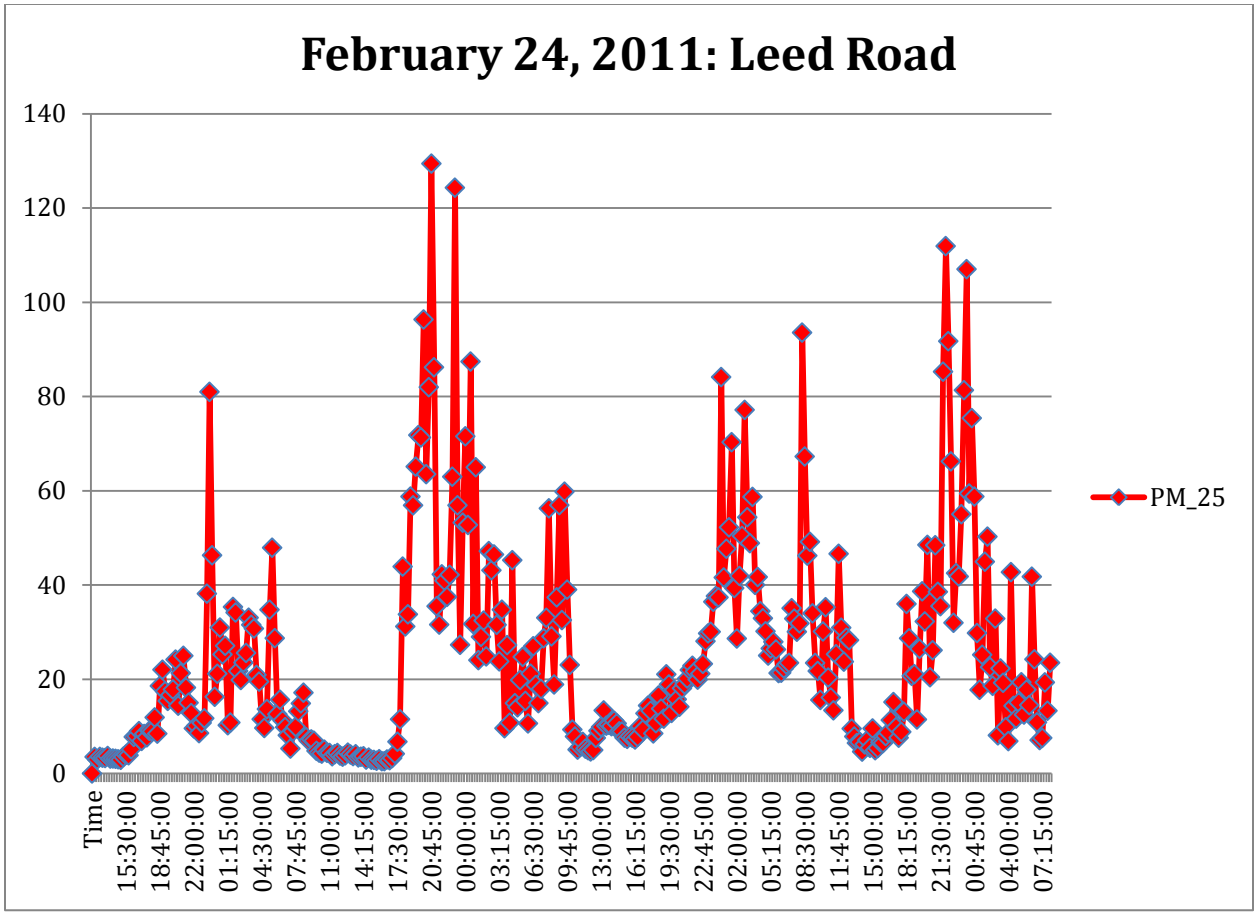

N
W
E
S
Particulate Matter Concentrations in Campbell River - February 20, 2010 (6:08 - 8:06 pm)
Feb 20 Pm 2.5 (ug/m^3)
0-1 ug
2-3 ug
4-6 ug
7-9 ug
10-19 ug
Summary Statistics:
Minimum: 0
Maximum: 19
Mean: 3.9
Standard Deviation: 3.3
0
1
2
Kilometers


Particulate Matter Concentrations in
Campbell River - March 4, 2010
(5:21-7:08 pm)
Feb 20 Pm 2.5 (ug/m^3)
0-1 ug
2-3 ug
4-6 ug
7-9 ug
10-13 ug
Summary Statistics:
Minimum: 0
Maximum: 13
Mean: 1.1
Standard Deviation: 0.8
0
1
2
Kilometers
N
W
E
S


Particulate Matter Concentrations in Campbell River - March 18, 2010 (5:45 - 7:43 pm)
Feb 20 Pm 2.5 (ug/m^3)
0-1 ug
2-3 ug
4-6 ug
Summary Statistics:
Minimum: 0
Maximum: 4
Mean: 0.3
Standard Deviation: 0.06
0
1
2
Kilometers
N
W
E
S

Appendix IV – Stationary Nephelometer Survey Results




February 24, 2011: Leed Road
140
120
100
80
60
40
20
0
Time
15:30:00
18:45:00
22:00:00
01:15:00
04:30:00
07:45:00
11:00:00
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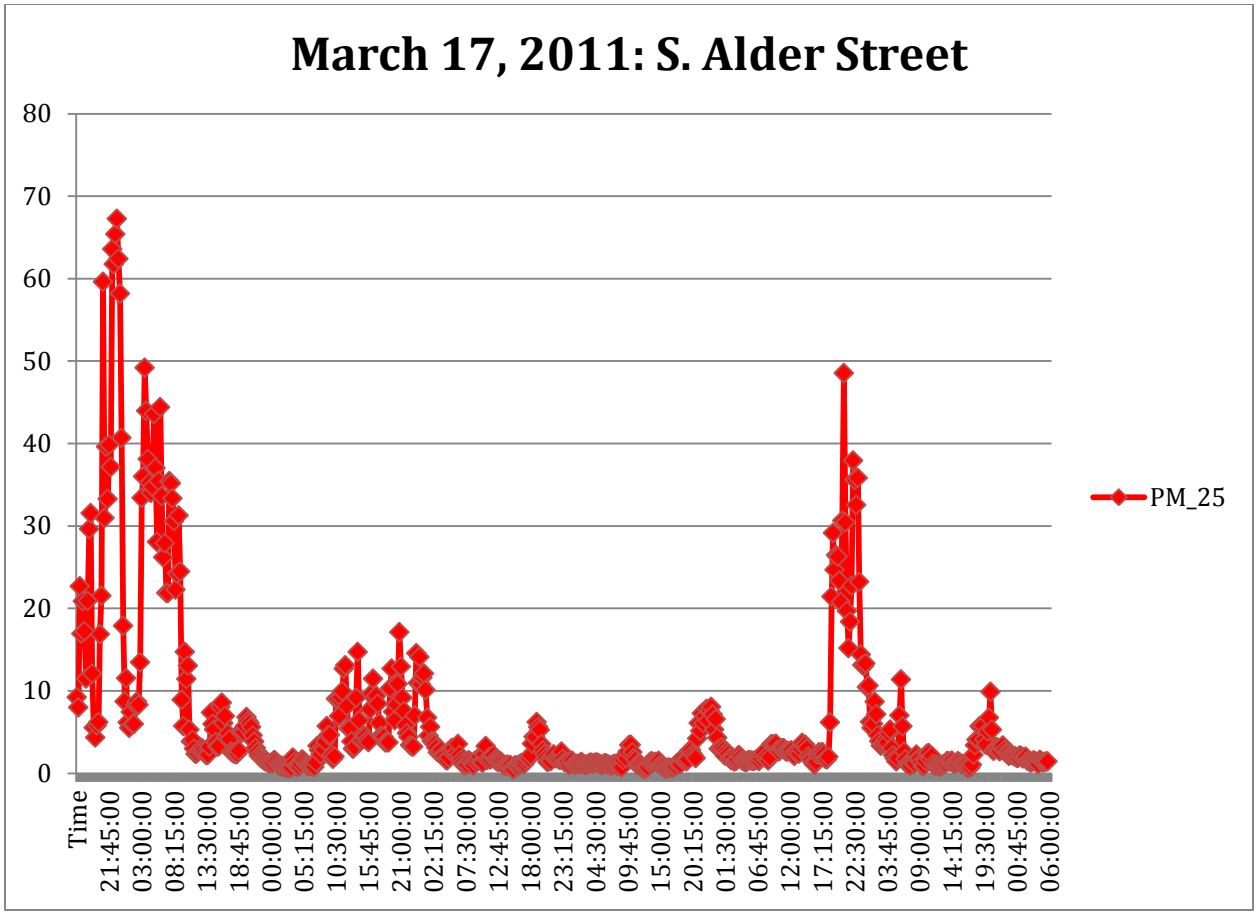
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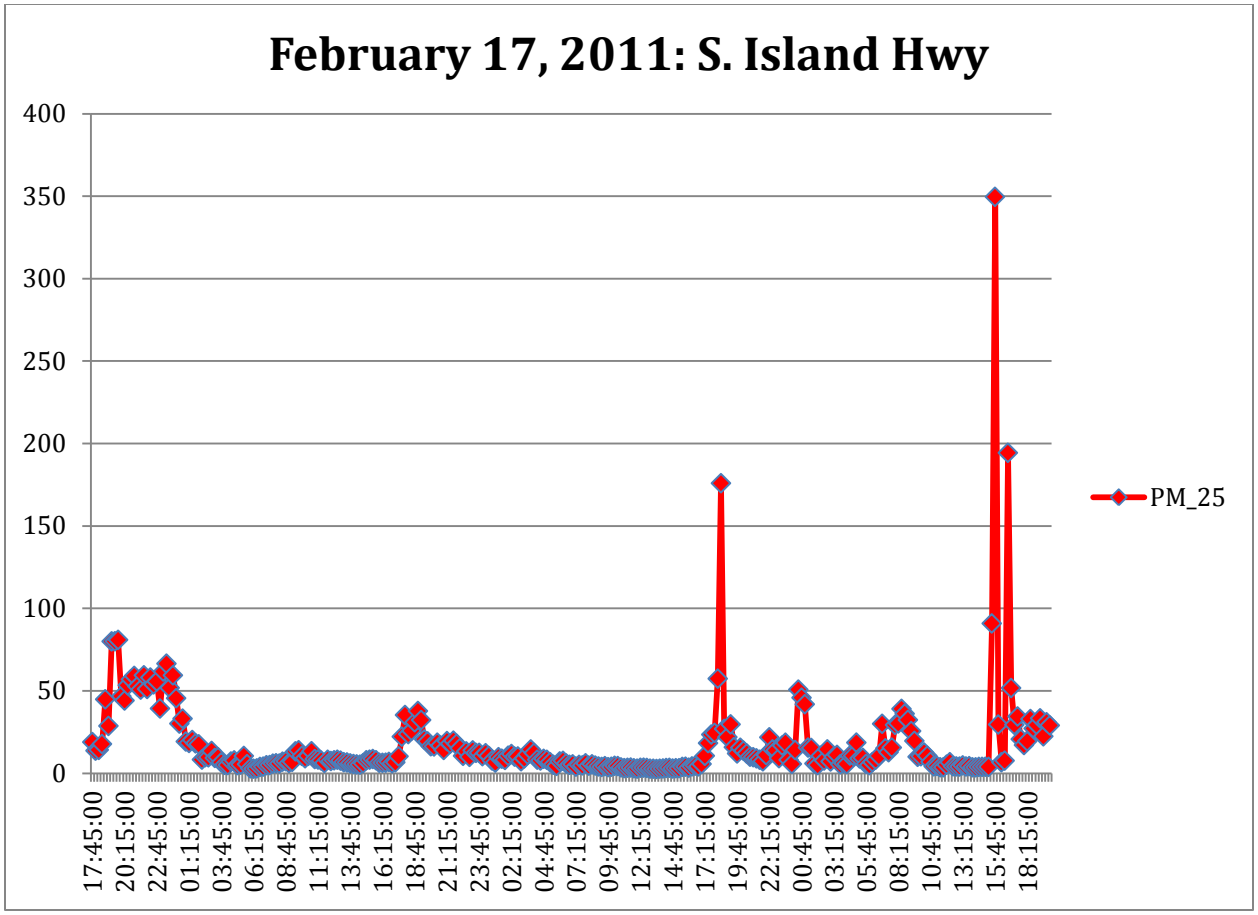
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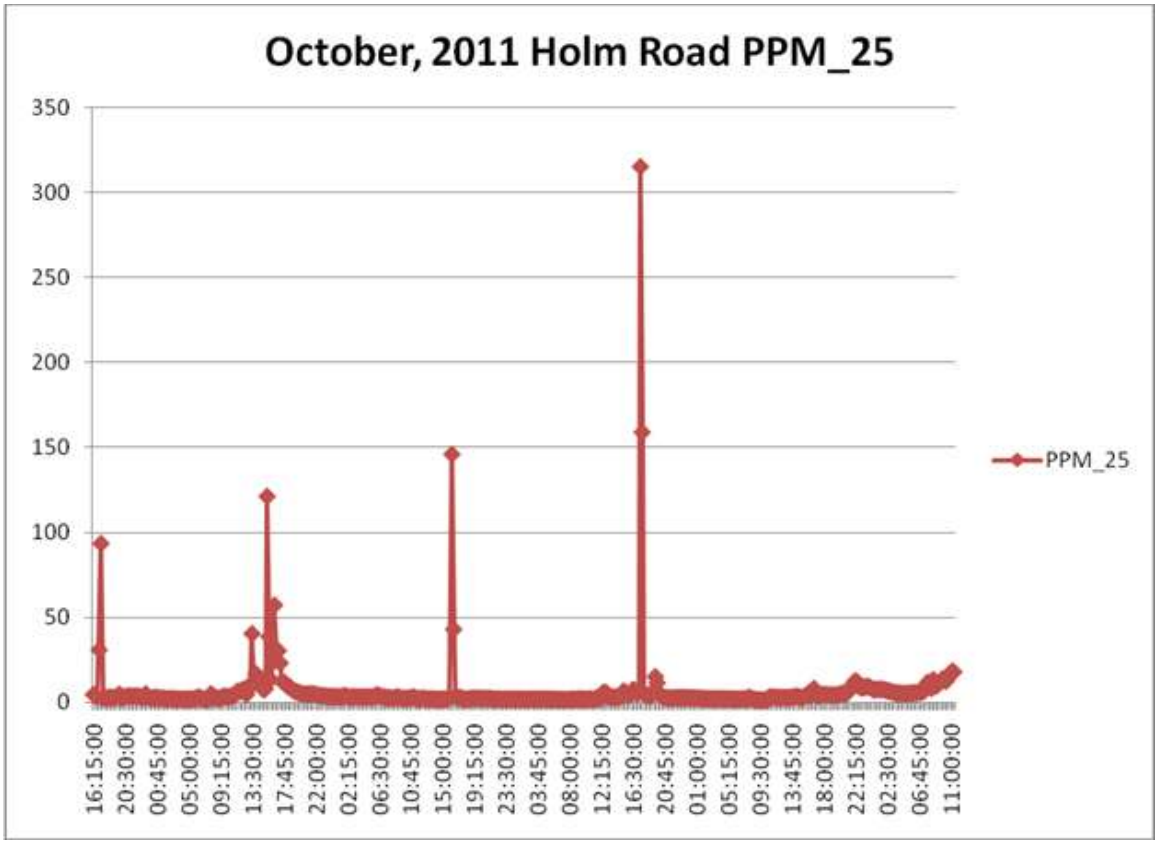
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Appendix V - City of Campbell River Air Quality Initiatives

1994	City of Campbell River Environmental Task Group released Wood Burning Appliance Smoke Management Plan
2000	City air quality tip line created by the Air and Water Quality Select Committee
2002–2003	Direct mail out of *Hot and Bothered about Smoke* pamphlet and a companion video produced and aired on local TV
2004-2006	Air quality initiatives focused on Clean Air Day in June during Environment Week through the promotion of transit (free rides)
2006	City of Campbell River Environmental Advisory Commission recommended a spring and fall yard waste pick up program as an alternative to backyard burning
2007	With yard waste pick up underway, the Clean Air Bylaw came into effect restricting back yard burning in the City of Campbell River
2008	City of Campbell River Environmental Advisory Commission recommended an amendment to the Clean Air Bylaw that all solid fuel burning appliances installed must have the Canadian CSA and/or US EPA certification. The Commission also recommended that the City participate in the Provincial Woodstove Exchange Program
2009	Provincial Woodstove Exchange Program funding secured to run a 2010 program and the Clean Air Bylaw was amended to regulate the certification of all new installations of solid fuel burning appliances workshops
2010	Five fine particulate air pollution surveys conducted with a nephelometer in known woodstove smoke pollution hotspots, *Burn it Smart* program delivered and woodstove exchanges conducted
	City of Campbell River's Corporate Green Team implements staff anti-idling policy
	Idle Free outreach conducted by City Bylaw officers adjacent to schools in partnership with School District 72
	Idle Free prompts (key fobs and decals) distributed at 3 community events

	Idle Free tips published in the Campbell River Courier Islander spring Live Green Guide
	Four Idle Free signs posted at City facilities (City Hall, Dogwood Operations, Community Centre and Centennial Park at the Pool)
	Idle Free signs posted at 2 out of 14 area schools
2011	Five ambient air quality surveys conducted in separate locations, *Burn it Smart* program delivered and woodstove exchanges conducted
	Six air quality staff presentations to School District 72 Green Teams and during Earth Week Celebrations
2012	Wood stove exchanges continue in partnership with five local retailers and *Burn it Smart* program delivered including a Neighborhood Air Quality Panel Discussion
2013	150 wood stove exchanges completed since the start of the program in 2010, Master Burner program initiated

Appendix VI – Woodstove Change-out Emissions Reduction Estimates

Conventional Wood Stoves:

Earle Plain – formerly AQ Met for the Cariboo Region estimated average emissions for a conventional (non-certified) wood stove in that region using figures from the 2005 report Residential Wood Burning Emissions in British Columbia (http://www.bcairquality.ca/reports/wood_emissions.html). The figures were average wood use, the emission factor for conventional stoves (23.2 kg PM/tonne wood), fir as a prevalent fuel type and a dry density for fir. From these an average annual emission rate from conventional stoves of **88.8 kg $PM_{2.5}$/yr** was calculated. This figure can be taken as somewhat representative of BC as the annual wood consumption in the Cariboo is intermediate between northern and southern BC. Sources of error in that assumption are the regional variation in wood types burned and the actual variation of fuel consumption from location to location. (As well there are a range of estimates for dry density of different wood species.)

Certified Wood Stove or Insert

Participants in the Provincial Wood Stove Exchange Program may opt to switch from an uncertified wood appliance to an EPA or CSA certified stove or insert.

The 2005 report gives an emission factor of 4.8 kg PM/tonne wood for certified stoves. This corresponds to an emission reduction of 80%. The EPA suggests emission reduction of about 70% will be realized (http://www.epa.gov/burnwise/energyefficiency.html) and the Puget Sound Clean Air Agency suggests emissions reductions of about 60% for wood burners in the Pacific NW (http://www.pscleanair.org/news/library/factsheets/30-104_wood_smoke_clean_heating_choices.pdf).

Using the EPA's suggested 70% reduction then equates **to 62kg/year reduction per change-out (from conventional to certified appliance)**. This is an average reduction, certified stoves are available with a significant range of measured emission rates, so individuals may realize more or less reduction. A large uncertainty is whether use of the appliance stays the same before and after change-out.

Natural gas

Participants in the Provincial Wood Stove Exchange Program may opt to switch from an uncertified wood appliance to a gas-fired appliance.

The emissions for natural gas conversion are estimated assuming that the individual replaces the same heat with natural gas as they obtained from wood

The energy content of Douglas fir is roughly 23 MMBTU/cord
Assume 3.9 cords burnt per year ➔ 89.7 MMBTU/year and assuming 60% efficiency for the conventional woodstove ➔ 53.8 MMBTU/year of useful heat.

To generate the same useful energy with an 85% efficient natural gas appliance we need 63.3 MMBTU/year energy from natural gas. Particulate matter emissions factor for natural gas combustion from AP42 (http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf) is 7.6 lbs Total PM /10^6scf gas = 7.45 *10^{-3} lb/MMBTU using a volume to energy conversion of 1020 BTU/scf.
7.45 *10^{-3} lb/MMBTU = 3.38 grams/MMBTU
Annual emissions (kg) of from gas appliance are (63.3 MMBTU/year x 3.38 grams PM/MMBTU)/1000

Annual emissions from gas appliance are 0.21 kg/year. So within a rounding error there are ZERO PM emissions from the natural gas appliance.

So the emissions reduction from a **conventional woodstove to natural gas appliance change out is 88.8 -0.2 = 88.6 kg/year $PM_{2.5}$.**

One concern with this calculation is that the burners who switch from wood to natural gas may not in fact be "average burners". A switch to natural gas may be most desirable for those who found (for whatever reason) that they were not using their wood burning appliance much. If this is in fact the case then the emission reductions from the wood to gas switch will be less than estimated above. But almost regardless of before and after usage, the PM emissions from burning natural gas are negligible in comparison with burning wood.

Pellet stove or Insert

Participants in the Provincial Wood Stove Exchange Program may opt to switch from an uncertified wood appliance to a pellet stove or insert.

EPA documents (http://www.epa.gov/burnwise/energyefficiency.html) suggest a reduction of 89% in switching from an uncertified stove to a pellet stove. Puget Sound Clean Air Agency also suggests emissions reductions of about 89% for wood burners in the Pacific NW who switch from an uncertified wood appliance to a pellet appliance. (http://www.pscleanair.org/news/library/factsheets/30-104_wood_smoke_clean_heating_choices.pdf). Emission factors from AP42 (http://www.epa.gov/ttnchie1/ap42/ch01/final/c01s10.pdf) suggest an 86% reduction from switching to pellets, and that is before accounting for the higher efficiency of pellet stoves. Finally the emission factors used in the 2005 MOE emissions report suggest a reduction of 90-95% depending which emissions factors are chosen.

Using the EPA/PSCAA figures the post change-out emissions from a pellet stove would be 9.8kg/year and the **emission reductions from switching to a pellet stove would be 79 kg/year.**