PRINCE GEORGE MOBILE MONITORING FINAL REPORT

April 29, 2011

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Submitted to: BC Clean Air Research Fund (BC CLEAR)
c/o Fraser Basin Council
1st Floor – 470 Granville Street
Vancouver, BC V6C 1V5

Submitted by: Northern Health Authority
Public Health Protection Division
4th Floor – 1600 Third Avenue
Prince George, BC V2L 3G6

and: BC Centre for Disease Control
Environmental Health Services Division
655 West 12th Avenue
Vancouver, BC V5Z 4R4

Prepared by Jennifer Hayek.

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1 EXECUTIVE SUMMARY

Air quality in Prince George is among the worst in British Columbia, with several exceedances of the Canada Wide Standard for fine particulate matter ($PM_{2.5}$) between 2000 and 2007. Exposure to fine particulate matter is linked to adverse human health impacts, including acute respiratory symptoms, chronic bronchitis, decreased lung function and premature death. The Prince George airshed is complex, with multiple fixed and area-based sources of air pollution. Management of the airshed is hindered by gaps in our understanding of the spatial distribution of ambient air pollution, including $PM_{2.5}$.

During the winter of 2009-2010, we conducted mobile monitoring in Prince George in an attempt to capture the spatial distribution of residential wood burning, at a neighborhood scale throughout Prince George. Mobile monitoring study results will complement the existing fixed Ministry of Environment (MOE) monitoring network by providing the resolution necessary to identify localized pollution "hotspots" within the airshed. At this point in time, only preliminary results are available which do not take factors such as meteorology and time of the night into account

This new understanding of the spatial distribution of ambient air pollution will not only support local airshed management planning efforts and air pollution control strategies, but will also provide a more detailed neighborhood "exposure" assessment for studying air pollution-related health effects. This information will also be used to increase public awareness and education around air pollution issues in Prince George.

This project could serve as a template for other communities interested in improving their understanding of the fine spatial distribution of ambient air pollution in their airsheds.

2 INTRODUCTION

Characterizing the spatial distribution of air pollutants within an airshed is important in terms of air quality assessment and understanding related health impacts. Data collected through mobile monitoring over small spatial scales can help to identify areas with high pollutant levels ("hotspots") and provide a better understanding of the spatial distribution and concentration of gradients of air pollutants within communities. Mobile monitoring is also useful for identifying potential focus areas or groups for epidemiologic studies and improving population exposure assessments.

In this project, we measured fine particulate matter (PM) throughout Prince George, British Columbia at a fine spatial resolution using mobile monitoring to characterize the spatial distribution of fine particulates from residential woodsmoke. Particulate matter has been a significant air quality issue in Prince George since at least the 1980s and has been monitored, at fixed locations, as PM_{10} since 1990 and $PM_{2.5}$ since 1994.

Exposure to fine particulate matter is linked to adverse human health impacts, including acute respiratory symptoms, chronic bronchitis, decreased lung function and premature death (Pope et al., 2002; Vedal, 1995). Management actions to reduce fine particulate in Prince George have met with mixed success and improvements to $PM_{2.5}$ levels have been slower than desired, with a slight downward trend emerging.

Mobile monitoring complements the existing fixed MOE monitoring network by identifying pollution "hotspots" within the airshed. This new understanding of the spatial distribution of ambient air pollution will not only be used to support airshed management planning efforts but will also provide a more detailed "exposure" assessment for researchers studying air pollution-related health effects.

3 BACKGROUND

3.1 Ambient Air Monitoring Network in Prince George

Prince George has many pollutant sources, as well as frequent light winds and thermal inversions that combine with valley terrain to trap pollutants. An extensive fixed monitoring network, funded by government agencies and industrial partners, measures a number of pollutants in the Prince George airshed, including $PM_{2.5}$, PM_{10}, sulphur dioxide (SO_2), nitrogen oxides (NO_x), total reduced sulfur (TRS), ozone (O_3), and carbon monoxide (CO) (Ministry of Environment, 2009).

Figure 1 depicts the locations of existing monitoring sites, while Table 1 sets out the pollutants measured (continuously and non-continuously) at each monitoring site in 2007.

Monitoring data for 2007 indicate that the Prince George BC Rail (BCR) monitoring site has the second highest annual average level of PM_{10} in BC (Figure 2), while the Prince George Plaza monitoring site ranks fifth overall in the province for annual average $PM_{2.5}$ (Figure 3).

Air quality advisories in Prince George are issued by the Ministry of Environment (MOE) when levels exceed and are expected to continue exceeding the BC ambient air quality objective of 25μg/m^3 or 50μg/m^3 (based on a 24 hour rolling average) for $PM_{2.5}$ and PM_{10} respectively. Figure 4 shows the number of advisories issued between 1995 and 2007.

Since monitoring began, and despite initiating several management programs (such as applying coarser winter traction material on roads) to reduce particulate matter, the annual average PM_{10} trend (Figure 5) remains highly variable.

The Canada Wide Standard (CWS) for PM , 24 hour average of 30μg/m^3 (98th percentile averaged over three years), was exceeded in Prince George for 2000-2002 (at 31.3 μg/m^3), 2001-2003 (at 35.0 μg/m^3), 2002-2004 (at 36.0 μg/m^3) and 2003-2005 (at 34.3 μg/m^3). Prince George was the only municipality in BC to have exceeded the $PM_{2.5}$ CWS. For the most current period (2005-2007), the Plaza monitoring site has been in compliance with the CWS to date, with an average 98th percentile result of 24 hour average level of 27.7 μg/m^3.

Figure 2, 3 & 6 all refer to risk. Risk is a calculation based on the number of μg/m³ days over 15 μg/m³ for $PM_{2.5}$ and over 25 μg/m³ for PM_{10} Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2004; Health Canada, 1997) and is representative of health problems associated with these pollutants.

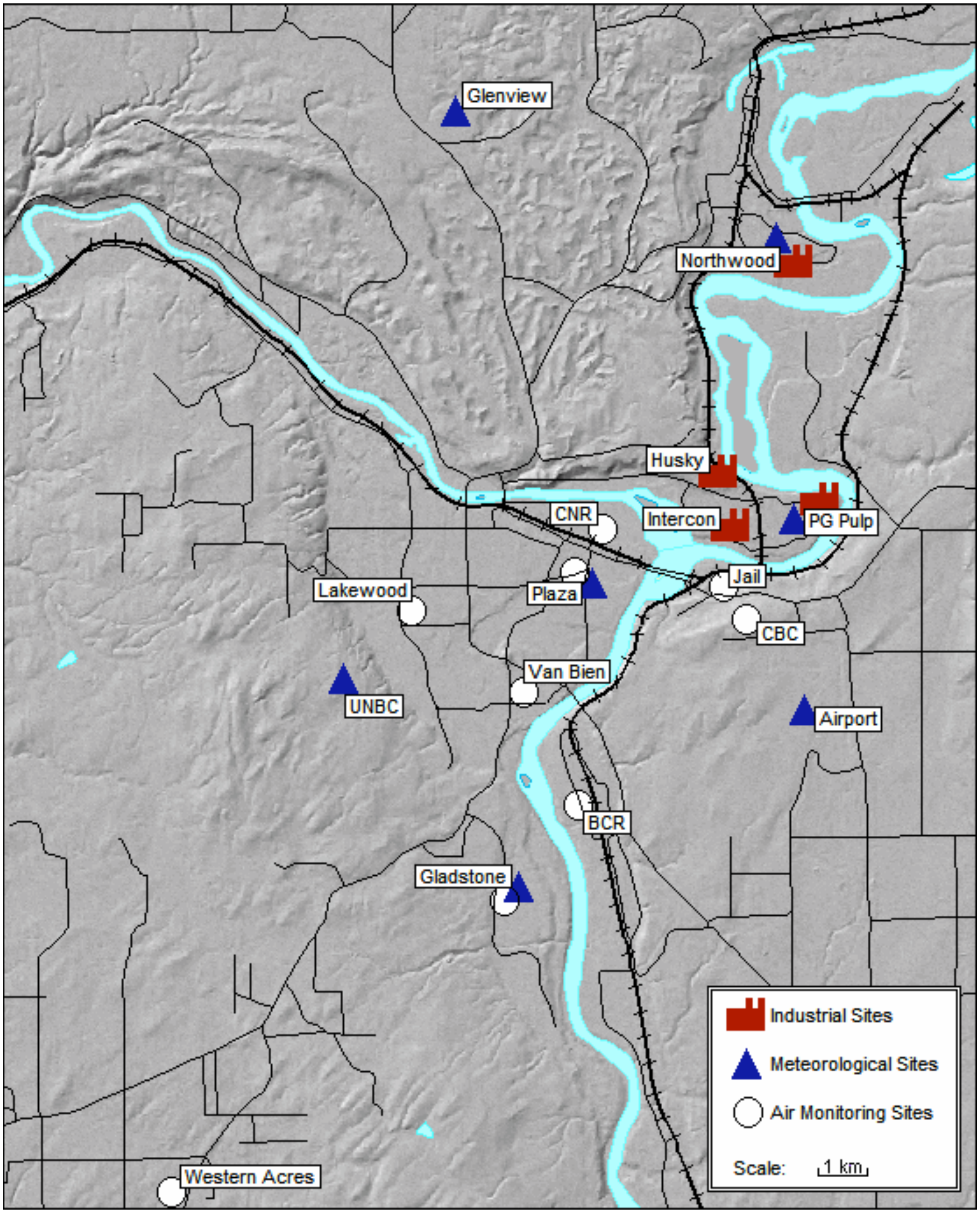

Figure 1: Location of Fixed Monitoring Sites and Meteorological Sites in Prince George (Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2009)

Table 1: Prince George Air Quality Monitoring Program, 2007 (Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2009)

Site No.	Location	Parameters
0450322	Jail	TRS, SO_2
0450307	Plaza	$\mathrm{PM}_{2.5}$, PM_{10}, PM_{10}, $\mathit{PM}_{2.5}$, TRS, NO_x, SO_2, O_3, CO
0450232	Van Bien School	PM_{10}, $\mathit{PM}_{2.5}$,
0450324	Lakewood Jr. School	PM_{10}, $\mathit{PM}_{2.5}$, TRS
0450270	Gladstone School	PM_{10}, $\mathrm{PM}_{2.5}$, $\mathit{PM}_{2.5}$, SO_2, WD, T, RH
E218771	CNR Site	PM_{10}
E224013	BCR Warehouse	PM_{10}
E209179	CBC Transmitter Site	SO_2
E259277	PG Western Acres	PM_{10}, $\mathit{PM}_{2.5}$
M109912	Plaza	WD, T, RH, SR
M109911	PG Pulp	WD, T
M109913	Northwood	WD, T
E224014	Glenview	WD, T
71908	Airport	WD, T, RH, SR, VIS, CC,PRC, PRS
-	UNBC	WD, T, RH, SR, PRS

Note: Non-continuous parameters are italicized

TRS = Total Reduced Sulphur Compounds (as H_2S)
SO_2 = Sulphur Dioxide
NO_x = Nitrogen Oxides (includes nitric oxide (NO) and nitrogen dioxide(NO_2))
PM_{10} = Particulate Matter less than 10 microns in size (Continuous)
PM_{10} = *Particulate Matter less than 10 microns in size (Noncontinuous)*
$\mathrm{PM}_{2.5}$ = Particulate Matter less than 2.5 microns in size (Continuous)
$\mathit{PM}_{2.5}$ = *Particulate Matter less than 2.5 microns in size (Non-continuous)*
O_3 = Ozone
CO = Carbon Monoxide
T = Temperature
WD = Wind Direction and Wind Speed
SR = Solar Radiation
RH = Relative Humidity
VIS = Visibility
CC = Cloud cover as well as cloud type and ceiling heights
PRC = Precipitation amount and type, including snow on ground
PRS = Barometric Pressure

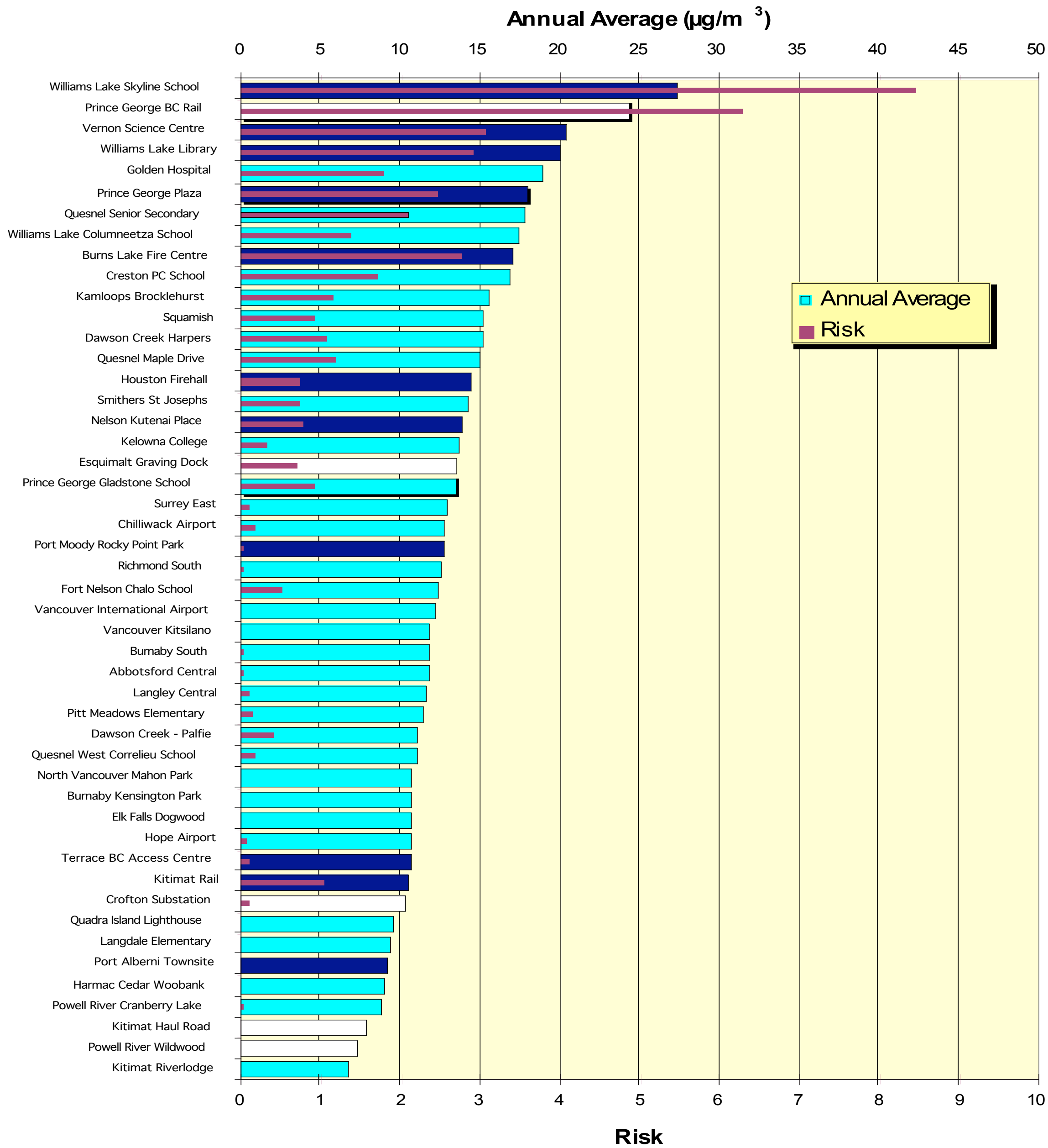

Figure 2: Continuous PM_{10} levels in British Columbia, 2007

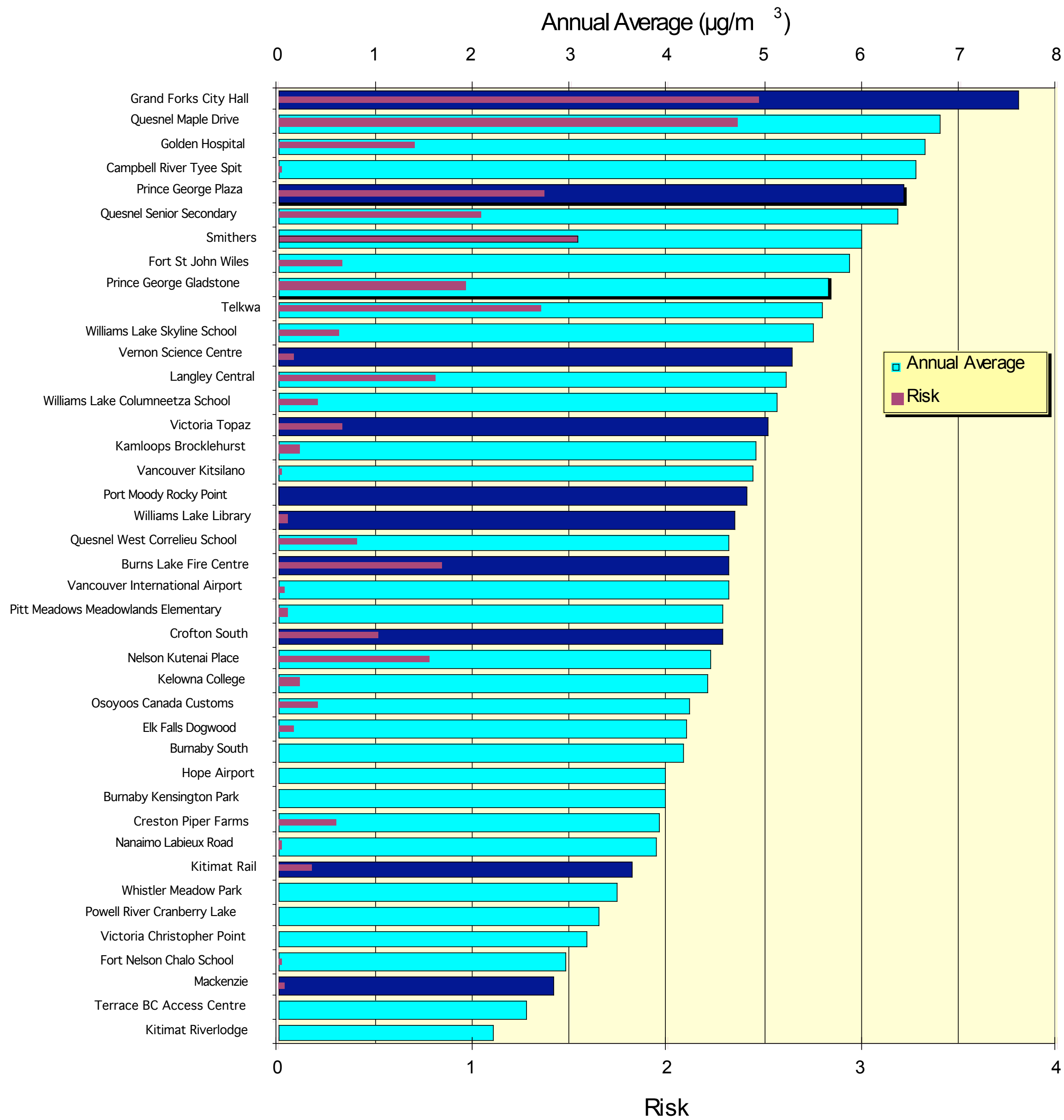

Figure 3: Continuous $PM_{2.5}$ levels in British Columbia, 2007

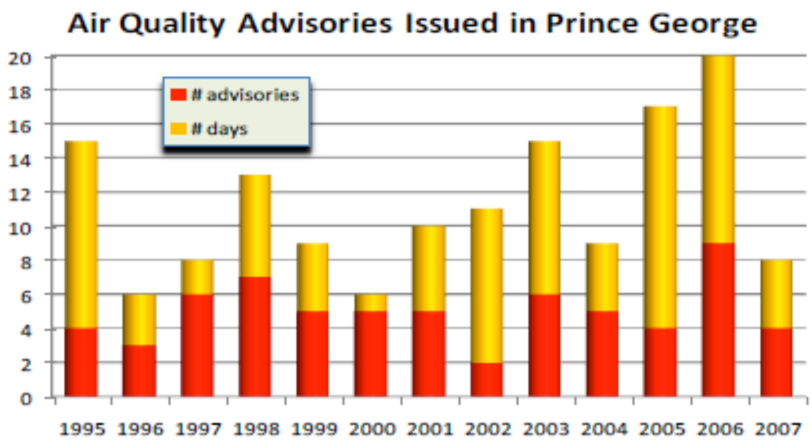

Figure 4: Air Quality Advisories Issued for Prince George between 1995 and 2007 (Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2009)

The $PM_{2.5}$ annual average trend (Figure 6) shows a rise in $PM_{2.5}$ levels between 1999 and 2003, a period when significant action was taken to reduce fine particulate matter. In particular, several beehive burners were phased out, an electrostatic precipitator was installed on a major industrial stack, several equipment upgrades to power boilers and energy units were made, and the City of Prince George commenced a road dust sweeping program that involved spraying road surfaces with water before sweeping to reduce fugitive dust. Yet, $PM_{2.5}$ levels increased instead of decreased, which indicates that area-based sources such as traffic and wood burning emissions may be more significant sources than originally believed.

Figure 5: Rolling annual average of continuous PM_{10} levels in Prince George between January 1995 and May 2010.

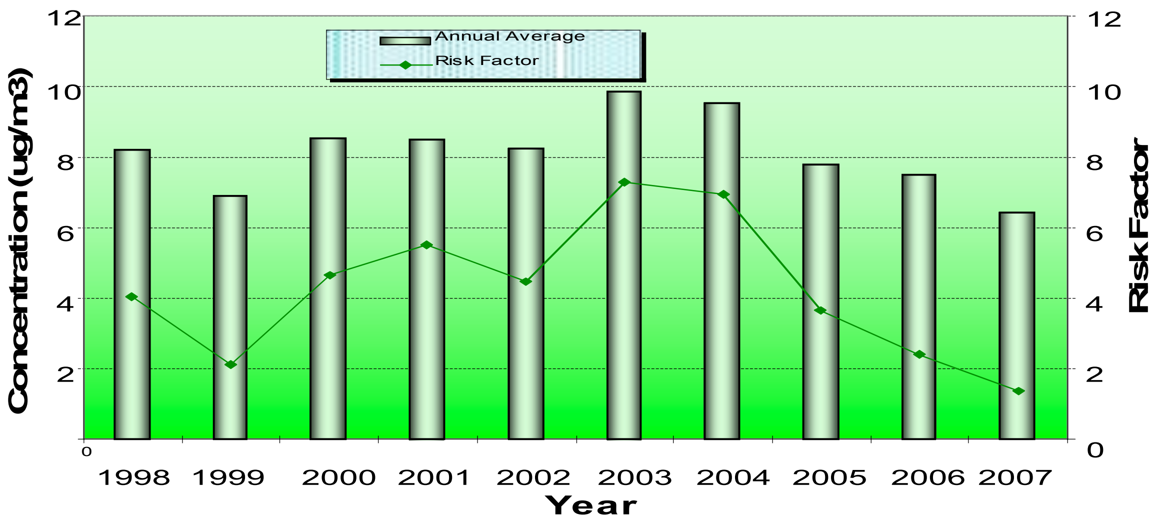

Figure 6: Rolling annual average of continuous PM2.5 levels at Plaza monitoring site, Prince George (Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2009)

3.2 Airshed Management in Prince George

Since 1995, air quality management in the Prince George airshed has been coordinated through a multi-stakeholder group (now known as the Prince George Air Improvement Roundtable (PGAIR)) comprised of representatives from government, Northern Health, industry, First Nations, community groups, the public and the University of Northern BC.

The Prince George Air Quality Management Plan identifies measures to improve air quality in the Prince George airshed, in particular to achieve acceptable levels of fine particulate matter. Recommendations included in Phase II of the Plan (2006-2009) outline action items to reduce emissions from residential wood burning and traffic sources, as well as to initiate mobile monitoring. A wood stove exchange program was held for three years: 2008-2010. An anti-idling campaign was also started to identify idling "hotspots" and also included a vehicle emission testing clinic for personal vehicles.

Recognizing the complexities inherent in identifying source contributions to fine particulate matter, major research studies were undertaken during Phase II of the Plan: a Chemical Speciation Study and a Source-Receptor Apportionment Study, as well as a micro-emission inventory and dispersion modeling. This research, is assisting PGAIR in prioritizing emission sources for reduction or other management actions during Phase III of the Plan.

3.2.1 Speciation Study: Results

Results from the speciation study indicate that three major sources contribute generally equal amounts of $PM_{2.5}$ to the Plaza monitoring site – industrial, wood-burning, and mobile emissions (Figure 7) – and support the indication that area-based sources such as traffic and wood burning emissions may be more significant sources than originally believed. Emissions apportioned to wood-burning sources also display a seasonal relationship, being high in winter (likely due to residential heating needs and meteorological factors) and low in summer; these results correlate well with ambient $PM_{2.5}$ values collected at the Plaza monitoring site.

This study used two different speciation techniques Chemical Mass Balance (CMB) and Positive Matrix Factorization (PMF) which gave similar results.

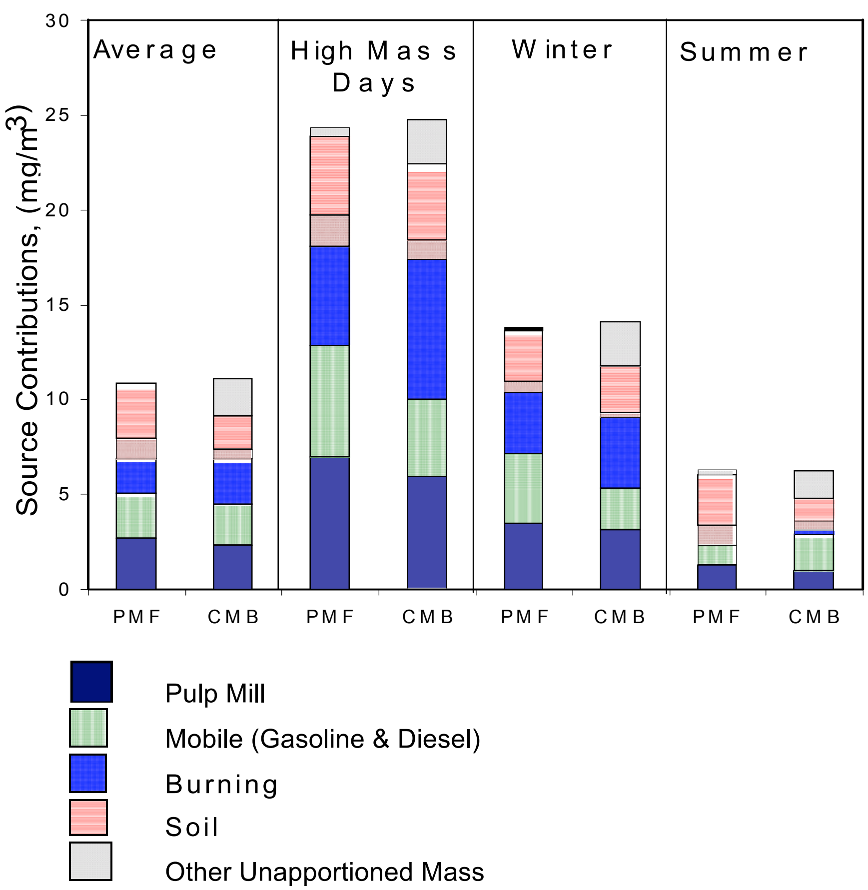

Figure 7: Comparison of PMF and CMB source contributions averaged over all data (average), the top 20% PM2.5 mass days (episodes), winter days, and summer days (Sonoma Technology, Inc., 2008)

3.2.2 Emission Inventory: Residential Wood Heating

Wood smoke can be a significant source of localized pollution. A total of three residential heating surveys have been conducted on the Prince George airshed, showing slightly variable results.

A provincial survey on residential wood burning emissions was conducted by Rensing (2005) for 666 homes in the City of Prince George and four communities in the Regional District of Fraser-Fort George. Approximately 25% of the surveyed homes reported wood burning appliance use as either a primary or secondary heating source. Extrapolation of these results (based on 840 interviews) indicates that there are approximately 8,985 wood burning appliances in use in the region. The amount of fuelwood consumed in each appliance averaged about three cords of wood over one heating season, yielding 308.8 tonnes of $PM_{2.5}$, as well as 35 tonnes of NO_x and five tonnes of So_x (both precursors to fine particulate matter) annually.

The Prince George Wood Burning Appliance & Residential Heating Survey was conducted by PGAIR and the City of Prince George in 2005. A heating survey that was mailed out to 20,598 Prince George city residents in 2005 elicited a response from 2,853 (13.9%) residents, providing general data on the types of wood burning appliances in homes: open fireplaces, conventional fireplace inserts over 15 years old, and conventional wood stoves over 15 years old. Fuel types (wood, natural gas, electricity etc.) were also classified as either a primary or secondary source of heating, with the data indicating most respondents (2,471 = 86.6%) are using natural gas to heat their homes. Wood and pellets are used as a secondary fuel source with 379 respondents using wood or pellets less than 51% of the time, and 75 respondents using wood or pellets more than 50% of the time.

Daily use patterns were also obtained showing minimal use of fuelwood during daytime hours (9:00AM to 3:00PM) with maximum peaks between 3:00PM and midnight. Seasonal variation in fuelwood use was also evident, showing near zero usage in summer, about two days per week in spring and fall, and four days per week in winter. Finally, respondents indicated that fuelwood use is two to three times greater on weekends than on weekdays.

The survey results were further analysed by a group of students in Prof. Jackson's ENSC 412/612 class (deHoog, Neil; Fisher, Daniela; Grafton, Warren, 2009). They provided a general breakdown of numbers of wood burning appliances by neighbourhood area (Table 2). This provided a useful starting point to target mobile monitoring efforts to corroborate survey results.

Table 2: Number of wood-burning appliances by neighbourhood (Prince George Residential Wood Heating Survey Results, 2005)

Neighbourhood Area	Number of Wood-Burning Appliances	Priority for Mobile Monitoring
College Heights	56	1
Heritage	26	2
Hart Highlands	24	3
North Nechako	17	4
Quinson	15	5
Central Fort George	14	6
Lakewood	14	6
Millar Addition	14	6
Foothills	12	7
Highland	12	7
Toombs	11	8
Crescent Heights	10	9
Pinecone	10	9

*Only those neighbourhood areas with more than 10 reported wood burning appliances are shown.

4 PROJECT OBJECTIVES & RATIONALE

The goal of this project was to measure and map the spatial variability of fine particulate matter ($PM_{2.5}$) attributed to wood burning appliance emissions within the City of Prince George. The primary objectives and associated rationales are as follows:

1. **To assess neighbourhood exposure of $PM_{2.5}$ from residential wood burning, to identify whether and to what extent there are significant, localized wood smoke "hotspots" (i.e. persistent elevated wood smoke concentrations) in neighbourhoods**

   Of the eight fixed air quality monitoring stations in Prince George (see Figure 1), $PM_{2.5}$ data are collected continuously only at two monitoring sites (see Table 1): the Plaza monitoring site, which is representative of the downtown "bowl" area (and represents a combination of commercial, industrial, and residential emissions) and the Gladstone monitoring site in lower College Heights (which is a major residential area with exposure to the industrial emissions as well). The location of the fixed monitors are not placed to pick up signals from highly localized sources such as woodstoves and traffic per se, but rather to monitor the cumulative impact of multiple pollution sources at sites throughout the airshed. This may result in a 'smoothing' out of ambient data such that significant short-term peaks in pollutant concentrations in extremely localized areas may be reduced or missed altogether. Therefore, the first objective of this study is to identify whether there are significant, localized wood smoke "hotspots" in Prince George neighbourhoods.

2. **To assess neighbourhood exposure of $PM_{2.5}$ from residential wood burning, to determine whether and to what extent wood smoke is a significant contributor to $PM_{2.5}$ levels in Prince George**

   The results of the residential heating surveys indicate a minor fraction of Prince George residents use wood as a primary means of heating. However, the conclusion of the speciation research identified burning as a major contributor to $PM_{2.5}$ levels. Therefore, a secondary objective of this study is to further investigate the findings of the chemical speciation research to determine whether burning seems to be a significant source.

3. To assess population exposure in wood smoke hotspots so to determine vulnerability and highlight priority neighbourhoods

The most important outstanding need that this study will address is to determine the number of people that are regularly exposed to pollution "hotspots" in Prince George and the associated health outcomes of prolonged exposure within these areas. Airshed management efforts to improve air quality should be prioritized on a population exposure basis and further categorized so that sensitive subgroups of the population (i.e. the elderly, children, those with respiratory ailments etc.) are identified and receive priority attention.

Measurement was conducted using mobile monitoring over small spatial scales (i.e. neighbourhoods). Results will be used to help in airshed management planning efforts (including the 2010 woodstove exchange program and public education and awareness) and develop effective air pollution control measures, as well as to assess population exposure to pollutants. This information is also useful for other communities in British Columbia impacted by emissions from residential wood burning. This study can provide valuable insight to other communities interested in improving their understanding of the spatial distribution of ambient air pollution in their airsheds.

5 PROJECT DESIGN & METHODOLOGY

For this project, two mobile monitors (nephelometers) were used (in conjunction with existing fixed-site monitors) to measure $PM_{2.5}$ to better understand the distribution of wood burning stove emissions within the City of Prince George. Mobile monitoring provides a means to capture the spatial variability of fine particulate matter over small spatial scales (e.g. neighbourhoods). Nephelometers measure the amount of light scattered by particulate matter to estimate the amount of particulate matter in ambient air. Continuous real-time measurement of light scattering from nephelometers can help to identify local particulate matter hotspots. Data collected from mobile monitoring can also be useful in classification of exposure to populations.

The project design and data collection methods were based in part on previous studies of wood stove emissions conducted by Larson et al. (2007) and by Millar (2008) and involve both mobile monitoring and fixed-site monitoring. Additional health data for Prince George will also be obtained for population exposure analysis relating to wood smoke related emissions.

Mobile monitoring entailed equipping a vehicle with a global positioning system (GPS) data logger and a nephelometer. Normally, nephelometer light scattering measurements are highly correlated with $PM_{2.5}$ concentration and can be readily converted into $PM_{2.5}$ mass concentrations by correlation with collocated data from an instrument that directly measures $PM_{2.5}$ concentrations such as a TEOM (Larson et al., 2007; Robinson et al., 2007). Nephelometers are readily portable and have the capability of taking high frequency measurements (e.g. as often as 1 second).

The GPS in this study, was programmed to log a geographic coordinate every five seconds and the nephelometer was programmed to record a measurement every ten seconds onto a laptop computer in the vehicle. An inlet funnelled air from outside the vehicle to the nephelometer and was positioned towards the rear of the vehicle so to prevent air from being forced down the inlet while the vehicle was in motion. The inlet was programmed to evaporate water droplets on the surface of the particles (a heater was activated when Relative Humidity was greater than 60%) and provide a better indication of particulate matter levels.

The vehicle was driven at a speed of 30km/h in residential areas. This meant that a nephelometer scattering value was taken roughly every 80m. Often, stop signs, traffic lights and turning around at the end of streets meant that nephelometer scattering which were taken at constant time intervals were thus taken at intervals shorter than 80m. In nonresidential areas such as along highways, the vehicle was driven at the speed limit. If the vehicle was traveling at 100km/h, there would therefore be a data point every 278m.

Quality assurance checks were carried out on the nephelometers on a regular basis. Span and zero checks were performed after the nephelometers had been operating for approximately 50 hours. Collocation data was also taken between the two nephelometers and between each nephelometer and the TEOM on an ongoing basis.

5.1 Study Area

The mobile monitoring project was designed in an attempt to capture the fine particulate levels from wood stove emissions in neighborhoods. Every single street in Prince George was monitored at least once and priority was placed on a population density basis as by where emissions of PM2.5 from woodsmoke was estimated to be the highest in previous studies. Figure 8 shows a map of Prince George with Divisions marked in different colors. The location of fixed site monitors is also visible on this map.

5.2 Mobile Monitoring Dates & Times

Mobile monitoring of wood stove emissions was conducted between December 2009 to April 2010, during cold, calm nights, along predetermined routes that focused on residential areas but that also aimed to capture the maximum spatial variability and concentration gradients within the community. Sampling dates were chosen based on meteorology associated with strong stable atmospheric conditions (e.g. stable high pressure ridges). These days are known to have the highest concentrations of PM2.5.

The project lead forecast the meteorological conditions needed for sampling. Consultations with more experienced meteorologists also took place. Generally forecasts were based on Environment Canada modeling (Regional Environmental Multiscale Model (REM) and Global Environmental Multiscale Model (GEM), Radar and Satellite images.

Nephelometers are not specific to particles from a particular source, though supplementary data including information relating to the location and time of measurement, together with chemical analysis of filter samples collected at the time of real-time measurements, can provide a better indication of the source

For example, wood smoke concentrations appear to be greater during late evenings, a time when emissions from some other $PM_{2.5}$ sources, including traffic, are less. Therefore, measurements collected during this time would provide information mainly on $PM_{2.5}$ concentrations due to wood smoke. Figure 9 shows that PM2.5 levels are highest during the evening. Generally sampling would begin at 6pm and last until about 2am.

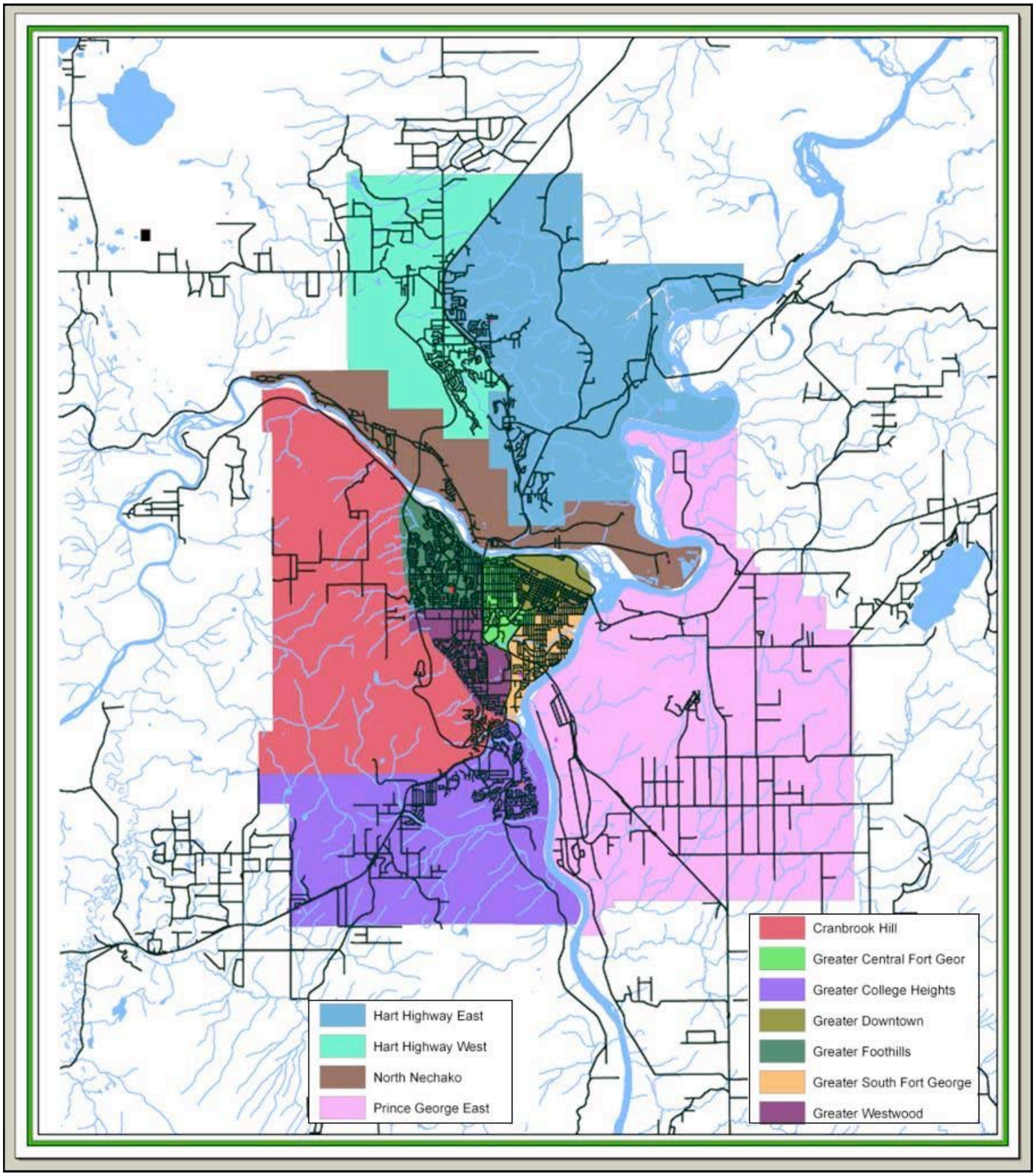

Figure 8: Map of Prince George and its 11 Divisions.

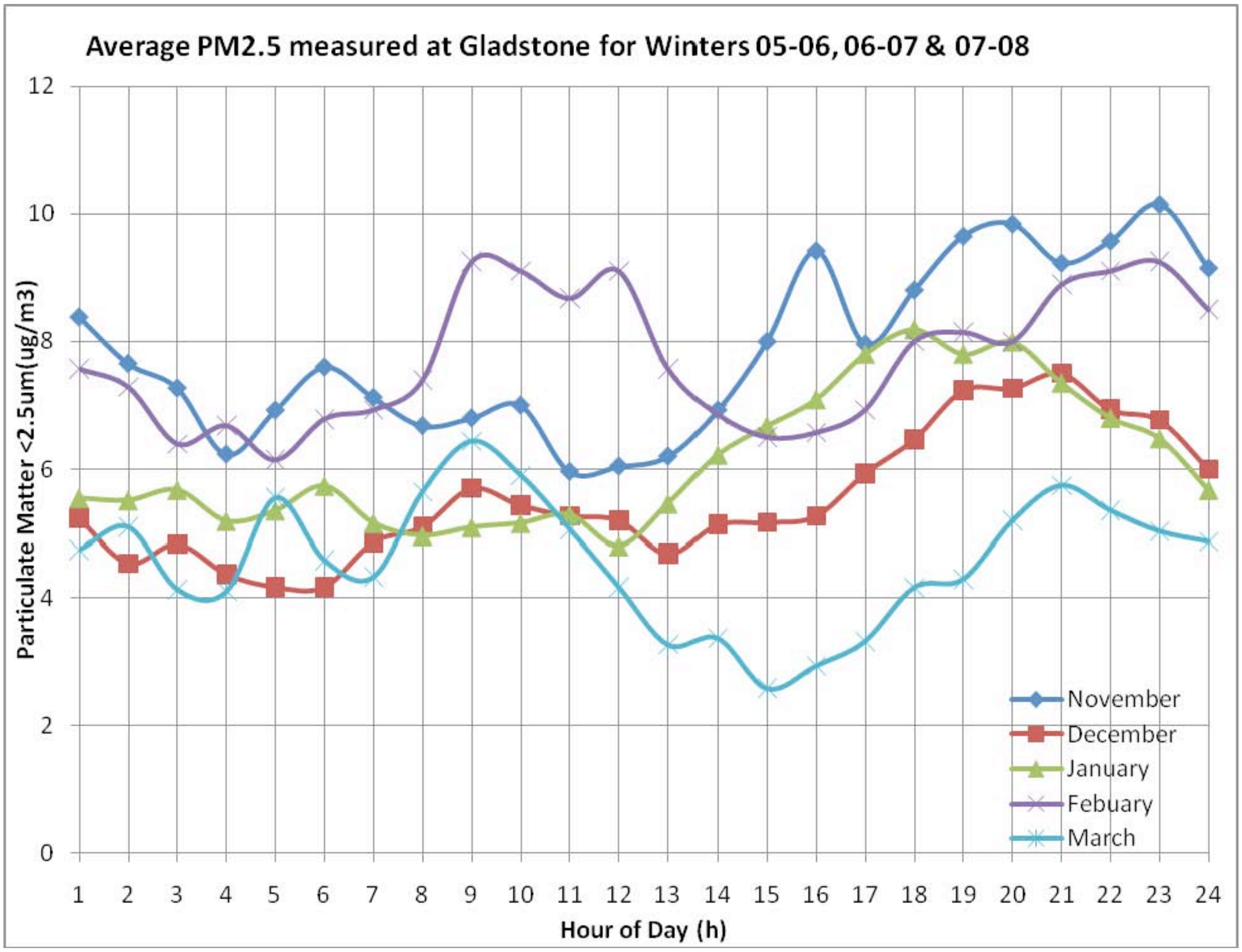

Figure 9: Average PM2.5 measured at a residential station in Prince George in previous years.

5.3 Route Design

Mobile monitoring routes were designed by a GIS specialist. A separate route was designed for each of the 11 Divisions in Prince George. A more detailed map of each division of Prince George is included in Appendix C. A copy of each of the routes is not included in this report because of size but may be made available upon request.

The routes were designed to include all roads in the city with minimal repetition. Occasional sections of road outside of city boundaries were included. Sections outside of the city's boundaries were considered to be less of a priority and driven only when time remained.

The routes initially incorporated every single road in the city. However, the routes were adapted throughout the season to remove non residential roads wherever possible so that the areas with the highest concentrations could be focused on.

Often, non-residential roads were traveled to go between residential areas.

An estimate on the amount of time a route would take was done based on the length of the route and a speed of 30km/h – the speed used for monitoring in a residential area. These estimates did not prove to be very accurate because stop signs, traffic lights and large amounts of turning the car around at the end of dead end streets made the routes take longer than estimated. During travel in non residential areas the vehicle would go faster than 30km/h, for example on highways(see Table 3). Overall, routes tended to take much longer than estimated. In eight hours, there was generally enough time to do one of the longer routes or two of the smaller routes.

At the end of the night the first 5-10 minutes of the route was repeated to provide data on how scattering values changed throughout the night.

Table 3: List of Routes, distance and estimated time of travel without starts and stops

ROUTE/ DIVISION	NAME OF ROUTE	DISTANCE OF ROUTE (km)	Speed Travelled (km/hr)	Total estimated time	
				hr	Min
1	Hart Highway West	162.321	30	5	24
2	Hart Highway East	148.034	30	4	56
3	North Nechako	74.714	30	2	29
4	Prince George East	243.344	30	8	6
5	College Heights	243.677	30	8	7
6	Cranbrook Hill	114.473	30	3	48
7	Foothills	107.755	30	3	35
8	Central Fort George	60.822	30	2	1
9	Downtown	50.384	30	1	40
10	South Fort George	74.702	30	2	29
11	Westwood	64.806	30	2	9

5.4 PM2.5 TEOM & Meteorological Sites

Meteorological and $PM_{2.5}$ TEOM data were collected from the fixed MOE monitoring sites (see Figure 1). The BC MOE validates all data collected at monitoring stations and stores the validated data as hourly averages in an archive which can be accessed online. One minute data are also available online and were used for the project.

The meteorological data were used to characterize atmospheric conditions during the mobile sampling. Plots of the meteorological data for each sampling night as well as concentrations of pollutants at the Plaza monitoring site are available in Appendix G. Plots of PM2.5 at Plaza and Gladstone as well as nephelometer scattering throughout sampling nights are available in Appendix H. TEOM data were also used to adjust nephelometer data (Section 6.4.1).

5.5 Nephelometer Inner Workings

Nephelometers are designed to measure light scattering ($\square_{sp}$). Light scattering in the atmosphere correlates with the amount of particulate matter suspended in the air. The units used to measure light scattering are inverse Megameters (M/m) where 1 M/m $=10^{-6}m^{-1}$.

The nephelometers used for this study were Ecotech M9003 Integrating Nephelometers. These nephelometers were borrowed from the School of Environmental Health at UBC. They were the same nephelometers that were used in 2007 for Gail Millar's Mobile Monitoring Study in the Bulkley Valley.

This nephelometer also measured the temperature of the air (T_A), the temperature of the light cell (T_c), relative humidity (RH) and atmospheric pressure (P).

The heated inlet is the large white tube on the top of the nephelometer in Figure 10. It attaches to the sample inlet (see Figure 10). Air samples are pulled through this inlet at a rate of 5 liters/minute. Air is brought straight through to the light cell (see Figure 11) where its scattering value is measured. Scattering is measured at a wavelength of 520nm.

If air samples contain a relative humidity larger than 60%, the heated inlet will come on automatically. Drying the air is essential at large values of relative humidity as it ensures that scattering values are not affected by humidity.

The instrument has a range of 0-2000M/m and a lower detection limit of 0.3M/m.

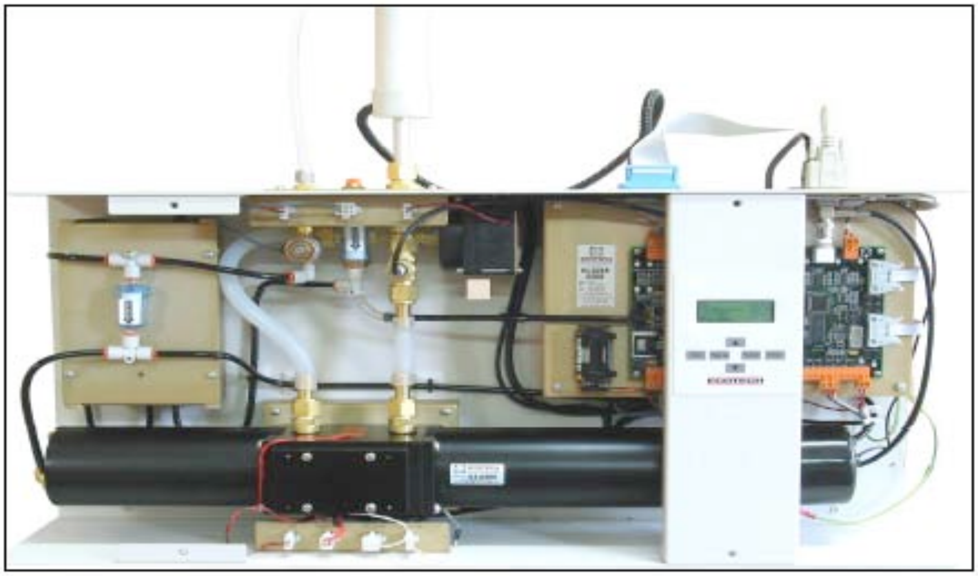

Figure 10: Inside of the M9003 Nephelometer (Reference: Ecotech, (2005) M9003 Integrating Nephelometer Operating Manual, Version 3.2)

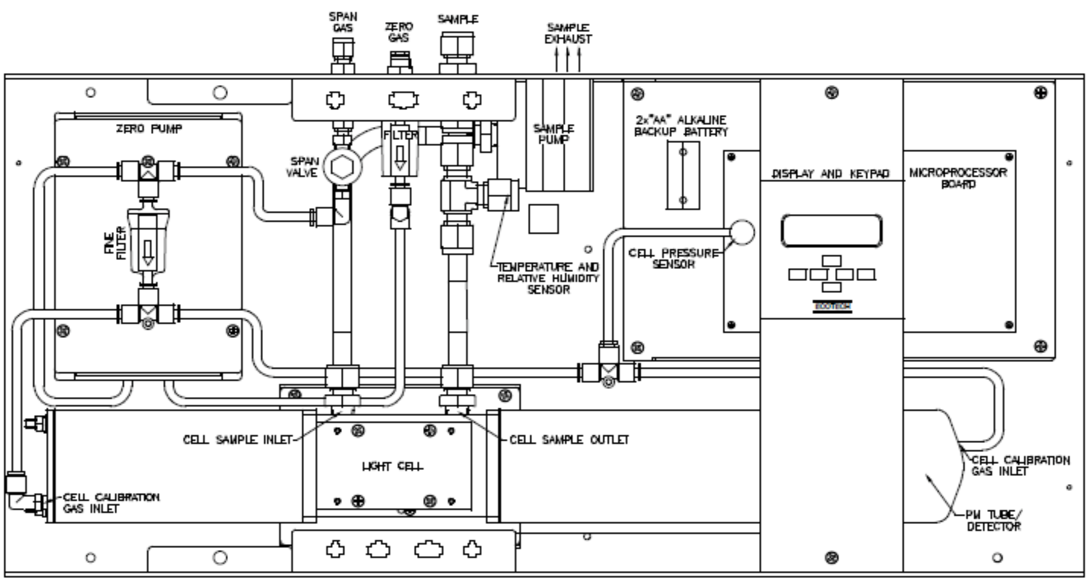

Figure 11: Part names inside the M9003 Integrating Nephelometer (Reference: Ecotech, (2005) M9003 Integrating Nephelometer Operating Manual, Version 3.2)

5.6 TEOMs

A TEOM (Figure 12), short for Tapered Element Oscillating Microbalance, draws air from the environment onto a filter where changes in oscillating frequency of a tapered element below the filter indicate the amount of particulate collected. (Environmental Quality Section, Environmental Protection Division, Ministry of Environment Omineca and Peace Regions, 2004) TEOMs provide continuous measurements; however, the data are more accurate after averaging to remove unrepresentative oscillations.

Figure 12: TEOM Monitor (ThermoScientific)

5.7 Nephelometer Maintenance

To ensure data quality a number of different quality control procedures were used. Please consult Section 8 in the nephelometer manual for details on nephelometer maintenance.

1) **Span Checks and Calibrations:** Span checks and calibrations were performed on the two nephelometers on a fairly regular basis using CO2. The procedure used was the one put in place for Gail Millar's study in the Bulkley Valley.
2) **Filter Changes:** Zero and span filters were changed on the instruments when there was concern.
3) **Collocation Data Collection:** See section5.8 as well as Appendix J
4) **Cleaning Measurement Cell:** The measurement cell was cleaned on each of the nephelometers at the beginning of the study and when a nephelometer did not pass a calibration. The measurement cell was normally cleaned with compressed air. Occasionally it was cleaned with alcohol on a Q-tip.
5) **Light Source:** The intensity of the light source was monitored on a regular basis.
6) **Leak Checks:** These were performed a couple of times throughout the study.

5.8 Nephelometer Collocation

Both Nephelometers were set up on the roof of Gladstone School (see Figure 1) between December 21 2009 and January 3 2010. In addition Nephelometer A was set up at Gladstone from November 30 to December 5 2009. Both nephelometers were set up on the roof of the Plaza Building (see Figure 1) between January 15-19. In addition, when the nephelometers were not being used for mobile monitoring they were often used to collect collocation data in the furnace and elevator room of the Plaza Building. In the elevator room, the nephelometers were attached to a vacuum line containing outdoor air. The PM2.5 TEOM along with numerous other air monitoring equipment attach to the same vacuum line. The elevator room provided what is thought to be an ideal location for collecting collocation data because the nephelometers could remain at room temperature in this indoor location while still monitoring outdoor air through the vacuum line.

The nephelometers were protected with enclosures made from plastic garbage containers as well as rain hats provided by the manufacturer whenever they were outside. This ensured that the instruments did not get wet. Also, whenever the nephelometers were collecting collocation data outside, heating pads were used on a low setting to keep the instruments from getting too cold. Generally the collocation data option was set to 5min averages.

5.9 Population Exposure

The hospital discharge data available for Prince George in the Canadian Institute of Health Information (CIHI) Discharge Abstract Database (DAD) and in the doctors' visit billing data (MSP) will be obtained from the Ministry of Health in Victoria. Respiratory and cardiac (circulatory) conditions with the following codes in International Classification of Diseases versions 9 and 10 (ICD 9 and ICD 10) will be downloaded and analyzed to the lowest postal code (neighborhoods) as recorded in the residence address of the patient:

ICD 9 codes:

Diseases of the Circulatory System: 350-459
Diseases of the Respiratory System: 460-529

ICD 10:

Diseases of the Circulatory System: I00 to I99
Diseases of the Respiratory System: J00 to J100

This analysis will be submitted in a separate document available soon.

6 DATA ANALYSIS

6.1 Quality Assurance of Nephelometer Data

The nephelometer data was rigorously QA'd and analyzed to assure the best results possible. The following QA procedures were applied:

1) Data which were marked as possibly from "diesel" or "exhaust" on the "Mobile Monitoring Sampling Sheets" (Appendix B) were removed.
2) The initial scattering values of "0.0000" when the nephelometer was first turned on were removed.
3) When there is more than a 5 second difference between GPS and Nephelometer time values the nephelometer scattering values were removed.
4) Initially all of the remaining nephelometer values were plotted so that the values on the way to and the way back from a division could be compared (these files are available upon request in the Ministry of Environment file system). Later, the majority of the nephelometer values outside of the designate divisions were removed except when values existed close by to the division that might not have been monitored on another night.
5) Areas where the vehicle was idling for long periods (perhaps when equipment checks were being performed) were removed as to not skew the percentiles.

6.2 Quality Assurance of TEOM Data

a) When TEOM data were missing they were replaced by the data for the closest minute. Generally missing TEOM data only occurred for a few minutes at a time and did not occur often.
b) When 1 minute averages were negative they were replaced by $1\mu g/m^3$.

6.3 Nephelometer, TEOM and GPS Data Manipulation

The Nephelometer and GPS data were formatted and adapted following "Time Matching Data Processing for Mapping Smoke (GPS and Nephelometer Data): Standard Operating Procedure Version 1.1" by J. Su, AM Baribeau which is available in Appendix D. The Time Macro referred to in these procedures is available in Appendix E.

Nephelometer and TEOM data were joined together using an Access code available in Appendix F.

6.4 Adjustments to Nephelometer Data

Firstly, the raw nephelometer/GPS data were plotted in ArcMap. ArcMap was made available for this project through UNBC. The mobile nephelometer data were first adjusted for within-evening variation. The data was not adjusted for between-evening variation to account for meteorological influences over time as originally planned because of the small amount of sample repeatability.

Although the project largely proceeded as initially proposed, some changes were made in how the data were analyzed and presented because of issues with the equipment (Section 8.1.4) and issues with the collocation data (Appendix J). With consultation from Prof. Peter Jackson it was decided that the best way to present the data would be in percentile form comparing results within an evening and not disclosing scattering values. It was also decided that because of nephelometer issues, the scattering values would not be converted to PM2.5 values. The following sections describe the details of the method used.

6.4.1 Adjusting Nephelometer Data within Evening

The datum from each night were looked at on a case by case basis. In the majority of cases the data were not adjusted for within-evening variation using TEOM data but in a few particular cases an adjustment was made. See Appendix H for details.

In cases where the data for a particular division and night was not adjusted using the TEOM data it was put into percentile form using the following formula:

$$b(\%) = {(\Sigma_{i=1}^{b-1} b)}/{(\Sigma_{i=1}^{n} b)} x100$$

Equation 1

where b refers to scatterings values, i refers to each 10 second period in a given division on a given night and therefore $\left(\sum_{i=1}^{n} b\right)$ refers to all nephelometer data for a given evening and $\left(\sum_{i=1}^{b-1} b\right)$ refers to all scattering values smaller than i.

Data was adjusted within evening when a time series from one of the TEOMs (Gladstone or Plaza) had the same shape as the nephelometer data. For example, if on a particular night the nephelometer data was low at the beginning of the night and then high near the middle of night and low again at the end of the night and if one of the two TEOMs had that same shape than it would be used to adjust the data. If neither of the TEOMs followed the pattern of the nephelometer then the data would not be adjusted. If the nephelometer remained at the same base level throughout the night then the data would not be adjusted using TEOM data. There is some subjectivity. This method was approved by Prof. Peter Jackson.

TEOM data used is always 1hour averages specific to each particular minute. The average is computed using each minute from 30 minutes before the minute until 29 minutes after the minute in question. The time period of 1hour was used as it was found to be most representative. Other time periods considered were 30 minutes, 45 minutes and 1.5hours. This experimentation data is available upon request .

In cases where the data for a particular division and night was not adjusted using the TEOM data it was put into percentile form using the following formula:

$$\frac{b}{PM(\%)\left(= \left(\sum_{i=1}^{\left(\frac{b}{PM}-1\right)} \frac{b}{PM}\right)\right)} \Bigg/ \left(\sum_{i=1}^{n} \frac{b}{PM}\right)^{x\mathbf{100}}$$ **Equation 2**

where b/PM refers to scatterings values divided by PM2.5 TEOM values, i refers to each 10 second period in a given division on a given night and therefore $\left(\sum_{n}^{i=1} \frac{b}{PM}\right)$ refers to all nephelometer data divided by PM2.5 TEOM data for a given evening and $\left(\sum_{\left(\frac{b}{PM}-1\right)}^{i=1} \frac{b}{PM}\right)$ refers to all scattering values divided by PM2.5 TEOM data smaller than i. This process is similar to Larson et al. (2007) except that the results are output in percentile form.

It was decided that results would be presented as four quantiles each representing 25% of the results. Quantiles will be distinguished by different colours. Because of the issues with the instruments we encountered and issues with the collocation data we felt that this was a conservative yet practical way of presenting the results. Results for this stage are in Appendix I.

6.4.2 Smoothing Results within Neighborhoods

The results were smoothed in GIS using the Spatial Analyst tool. The output cell size and shape chosen was circles with radii of 50m. This means that data within 100m of a data point was averaged in each output cell. Results are available in Section 7.

6.4.3 Adjusting Nephelometer Data between Evenings

Smoothed nephelometer results from section 6.4.2 were not averaged between evenings because of the low number of repetitions of divisions and because there tended to be a large variation in the results on different nights.

6.4 Population Exposure to Woodstove Emissions

Collected hospital discharge data from 1997 to 2006 for both sexes and all ages will be analyzed and submitted in an additional report. The output of the analysis will be at the aggregate level to eliminate confidentiality or privacy concerns.

The analysis will compare annual rates of hospitalizations and physician office visits for the selected respiratory and circulatory conditions for areas in Prince George with significant as well as those with low or no measures of fine particulate matter. The analysis will include trend analysis and age-sex comparisons. Appropriate statistical tests will be done for significance.

A technical summary is as follows:

Ages: All ages
Sex: Male, Female and both sexes together
Period of Analysis: 1997-2006
Level of Analysis: Aggregate
Location: City of Prince George
Geographic Level of Analysis: Postal Code
Type of Data: ICD 9 or ICD 10 Codes in the Diagnostic Fields in the

DAD and MSP databases
Output: Aggregate

7 RESULTS

In the following figures the lowest quarter of the nephelometer scattering values for a particular division and night are in green, the second lowest quarter by a yellow dot, the second highest quarter in orange and the highest quarter of the values in red.

See explanations in Section 6 for further background information as well as Section 8 for a discussion of the results.

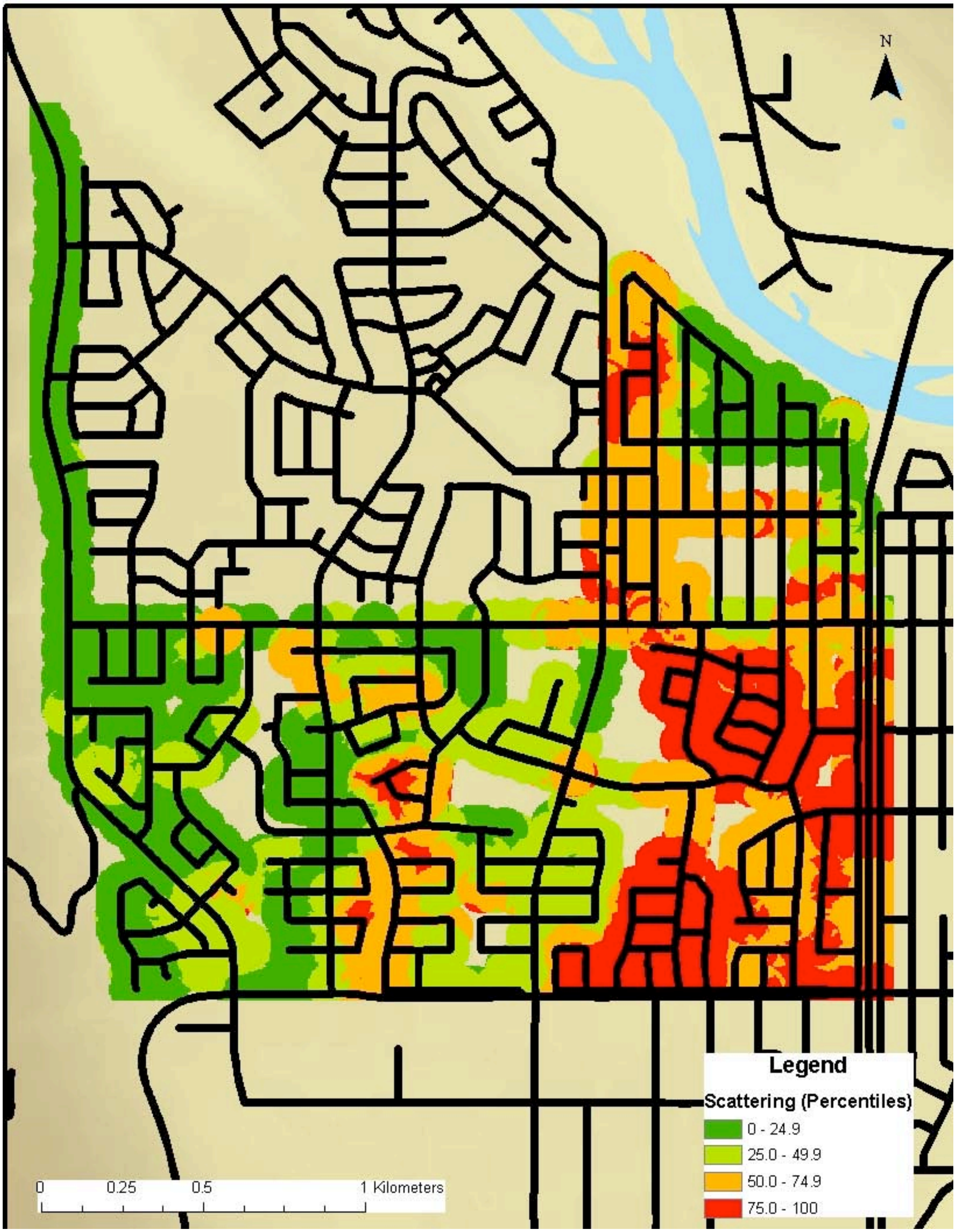

Figure 13: Smoothed Scattering Values (Percentile Form) for the Foothills Division of Prince George, December 9, 2010

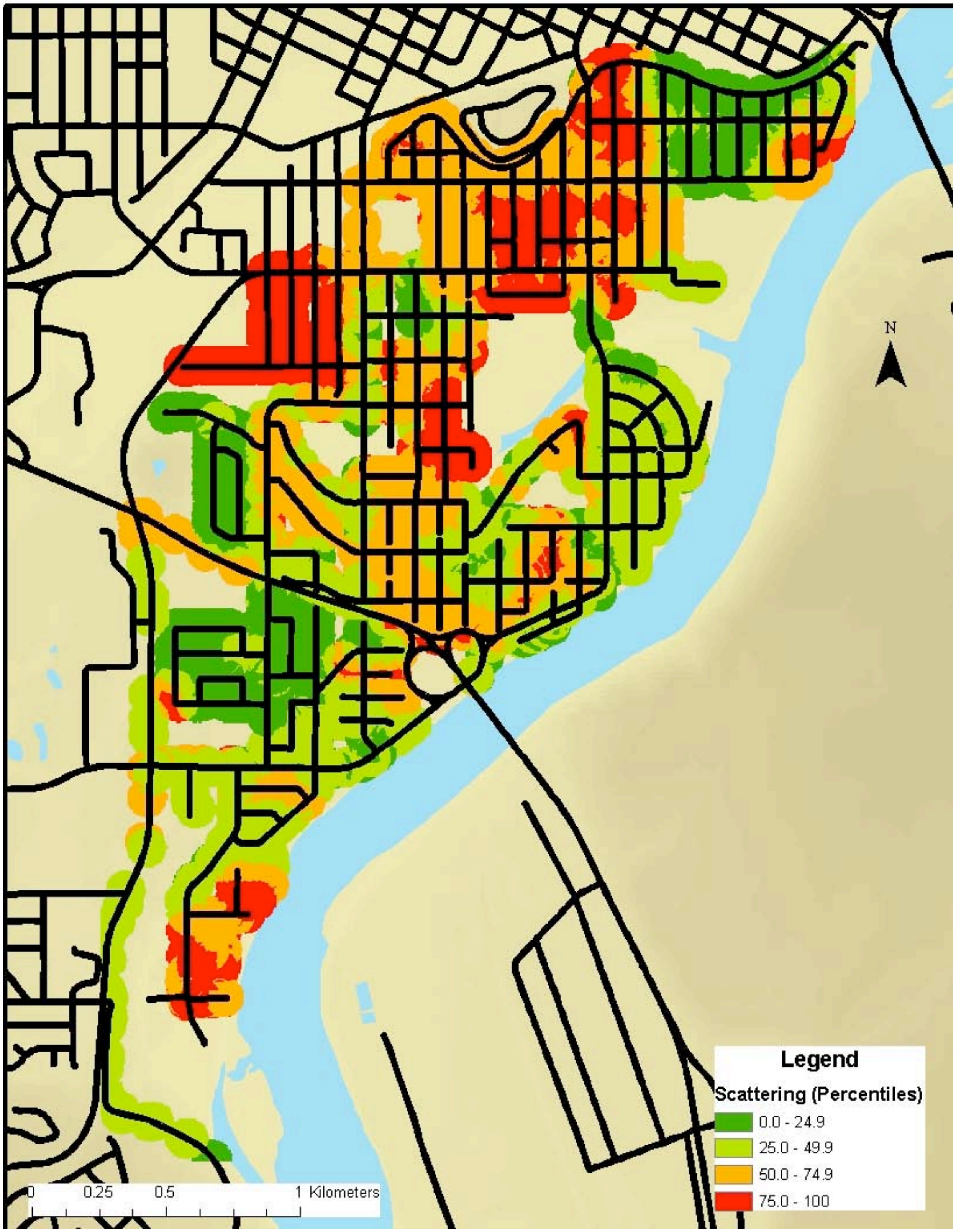

Figure 14: Smoothed Scattering Values (Percentile Form) for the South Fort George Division of Prince George, January 3, 2010

Figure 15: Smoothed Scattering Values (Percentile Form) for the Westwood Division of Prince George, January 6, 2010

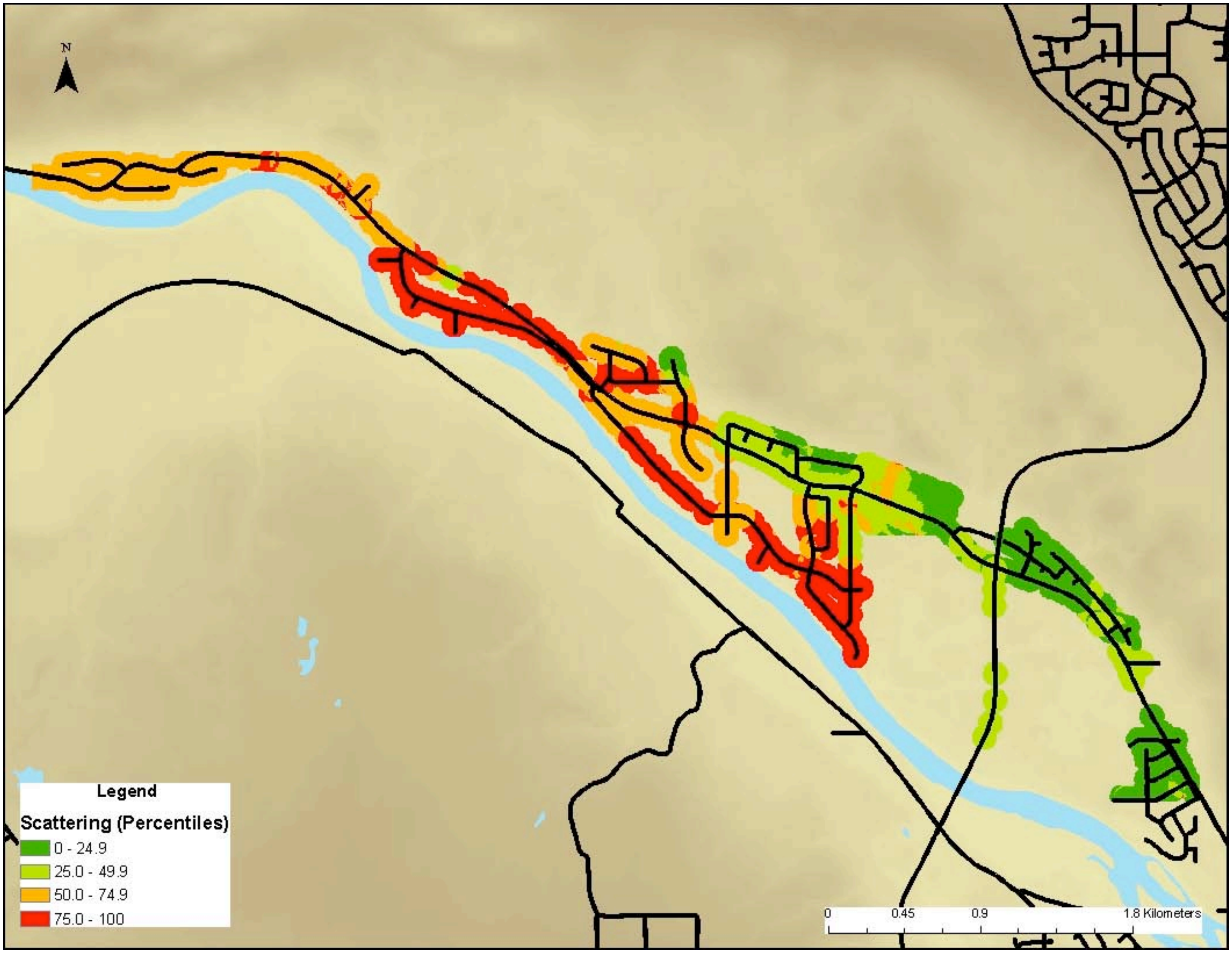

Figure 16: Smoothed Scattering Values (Percentile Form) for the North Nechako Division of Prince George, January 7, 2010

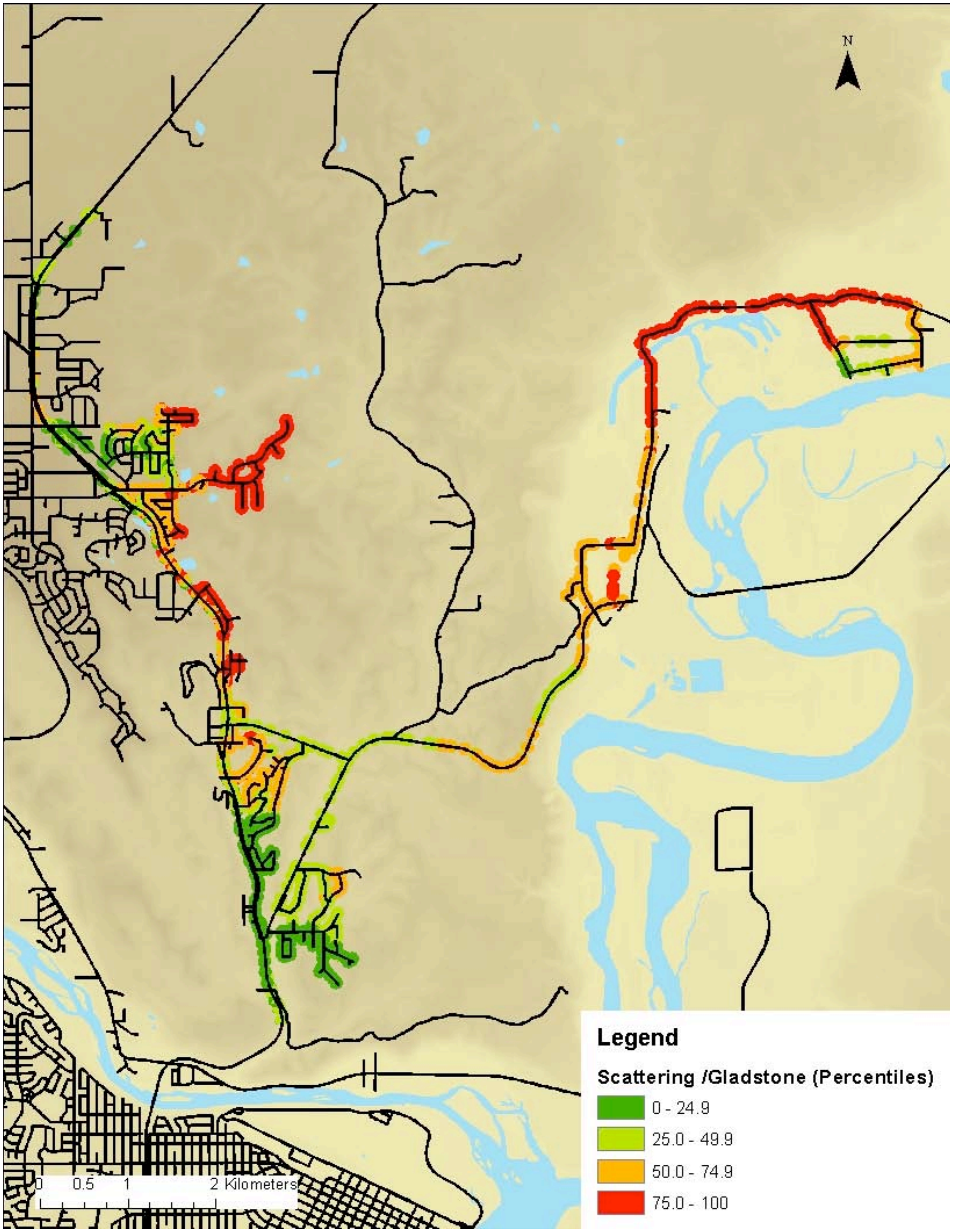

Figure 17: Smoothed Scattering Values (Percentile Form0 for the Hart East Division of Prince George, January 8, 2010

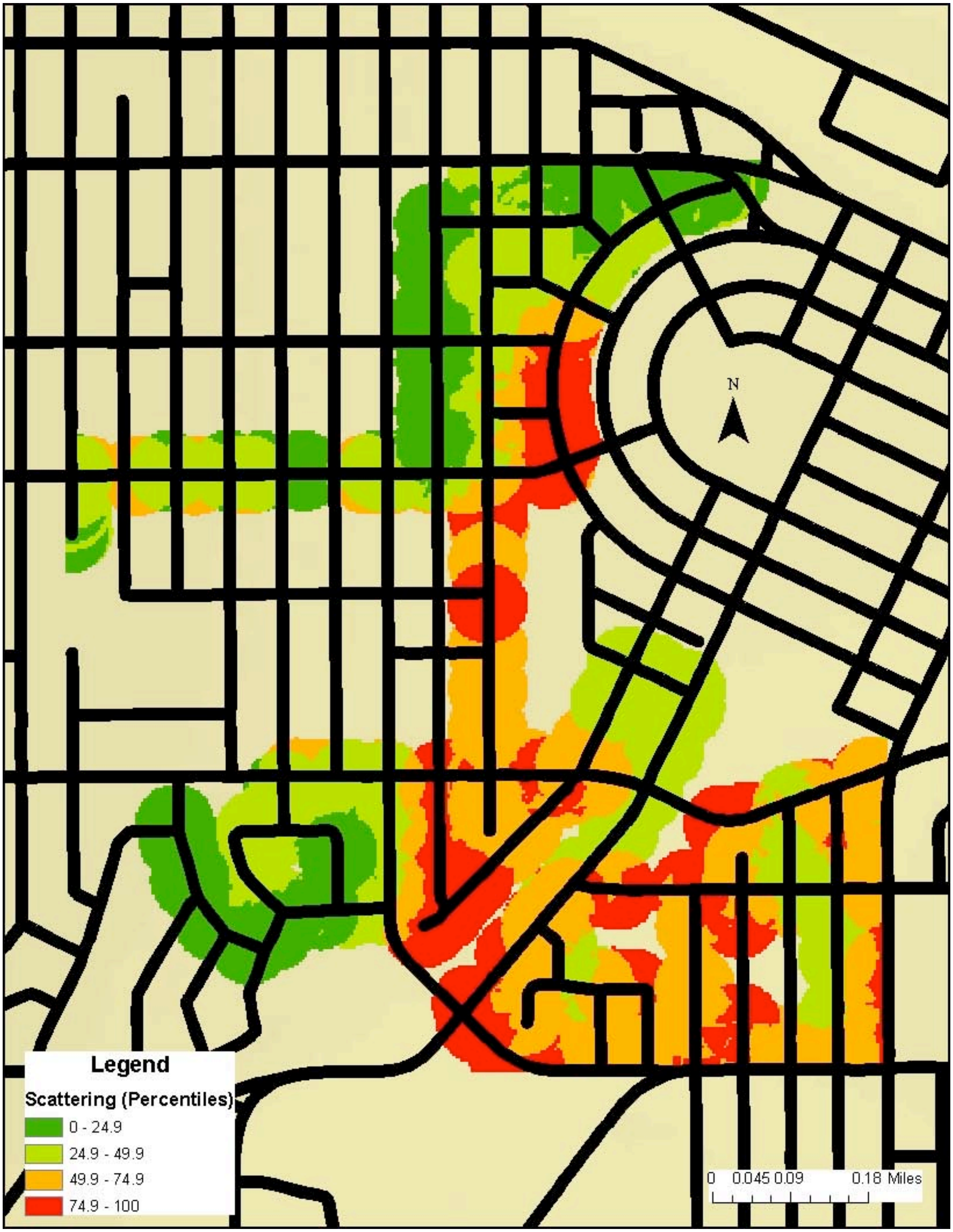

Figure 18: Smoothed Scattering Values (Percentile Form) for the Central Division of Prince George, January 22, 2010

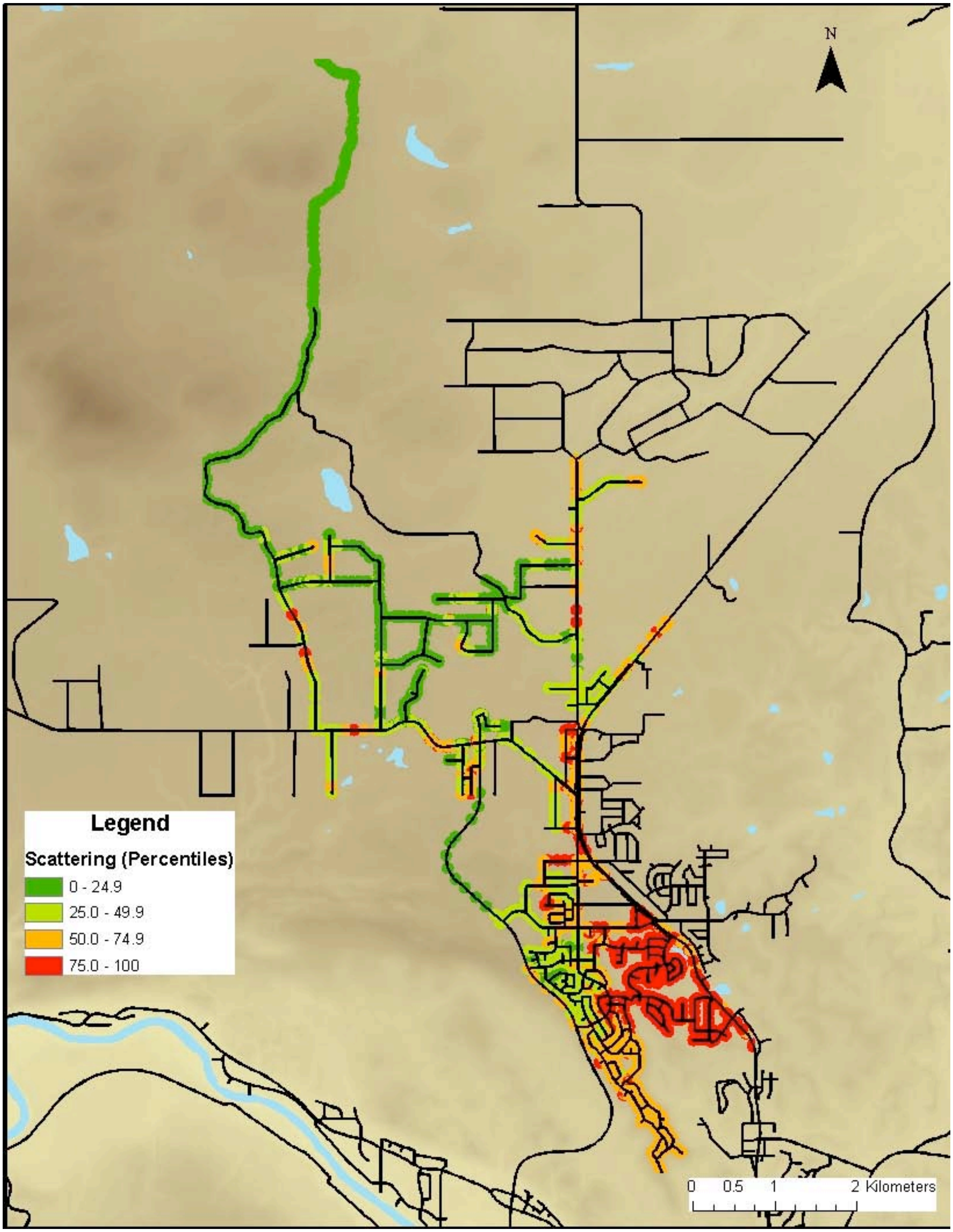

Figure 19: Smoothed Scattering Values (Percentile Form) for the Hart West Division of Prince George, January 23, 2010

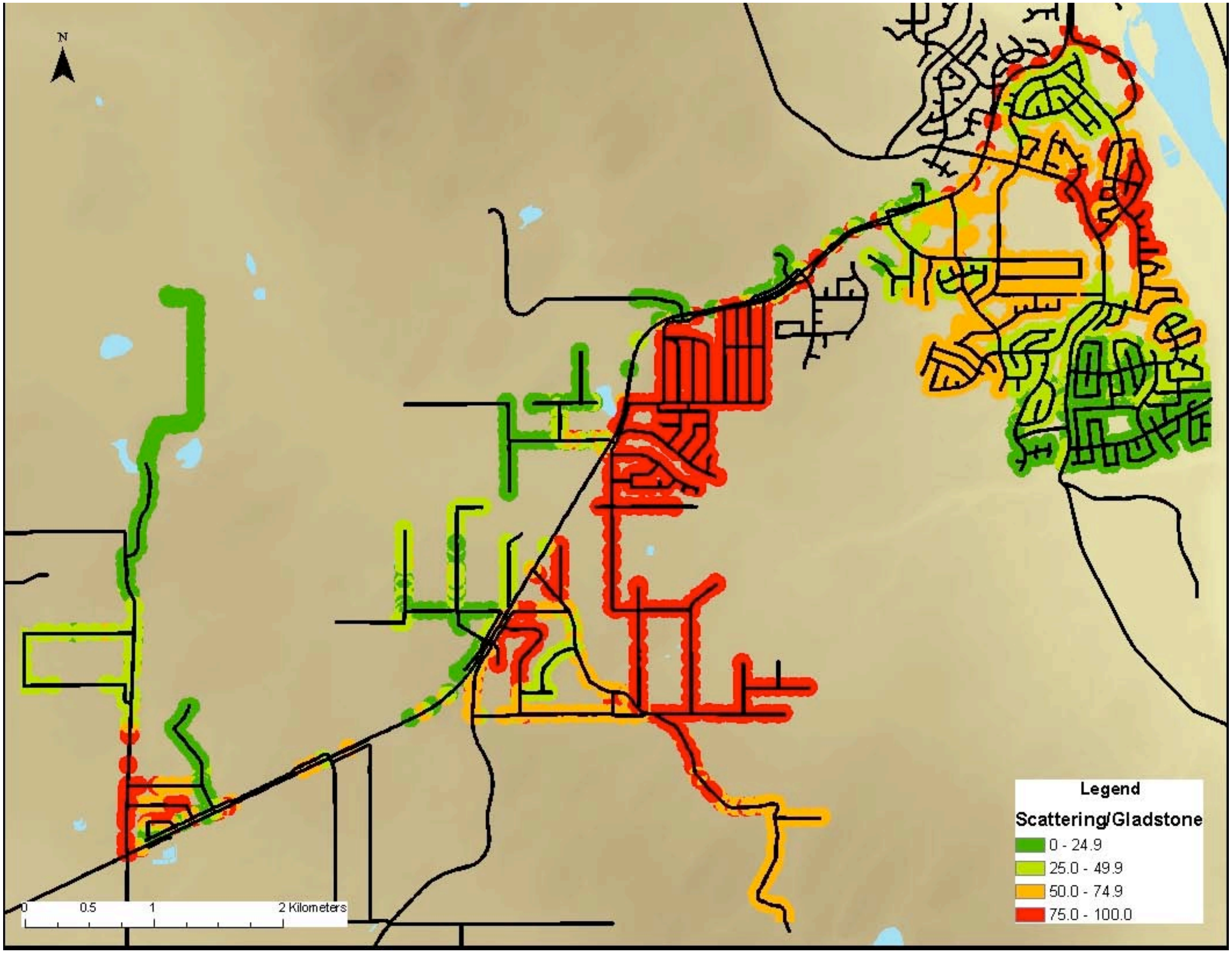

Figure 20: Smoothed Scattering Values (Percentile Form) for the College Heights Division of Prince George, January 23, 2010

Figure 21: Smoothed Scattering Values (Percentile Form) for the Downtown Division of Prince George, January 26, 2010

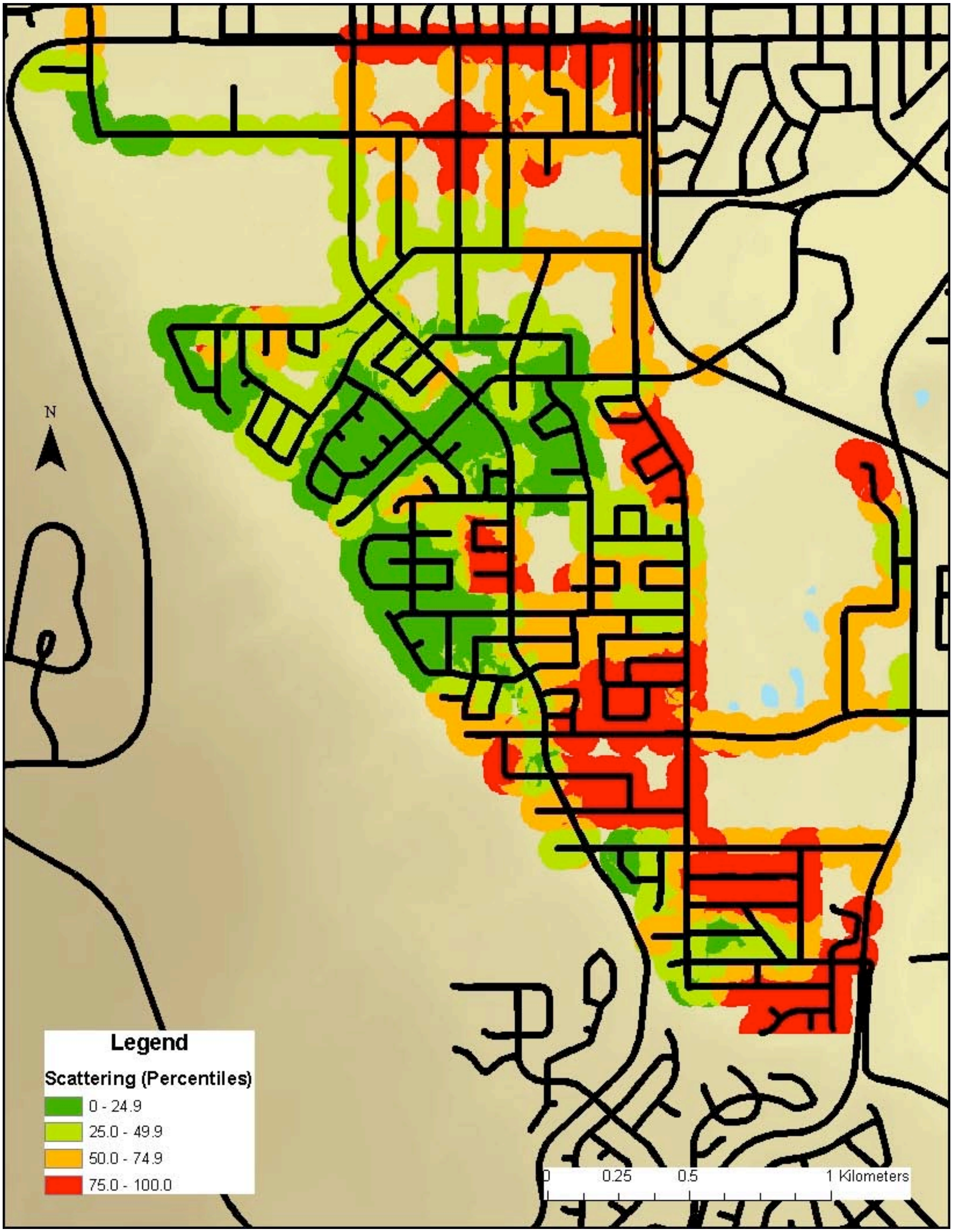

Figure 22: Smoothed Scattering Values (Percentile Form) for the Westwood Division of Prince George, January 26, 2010

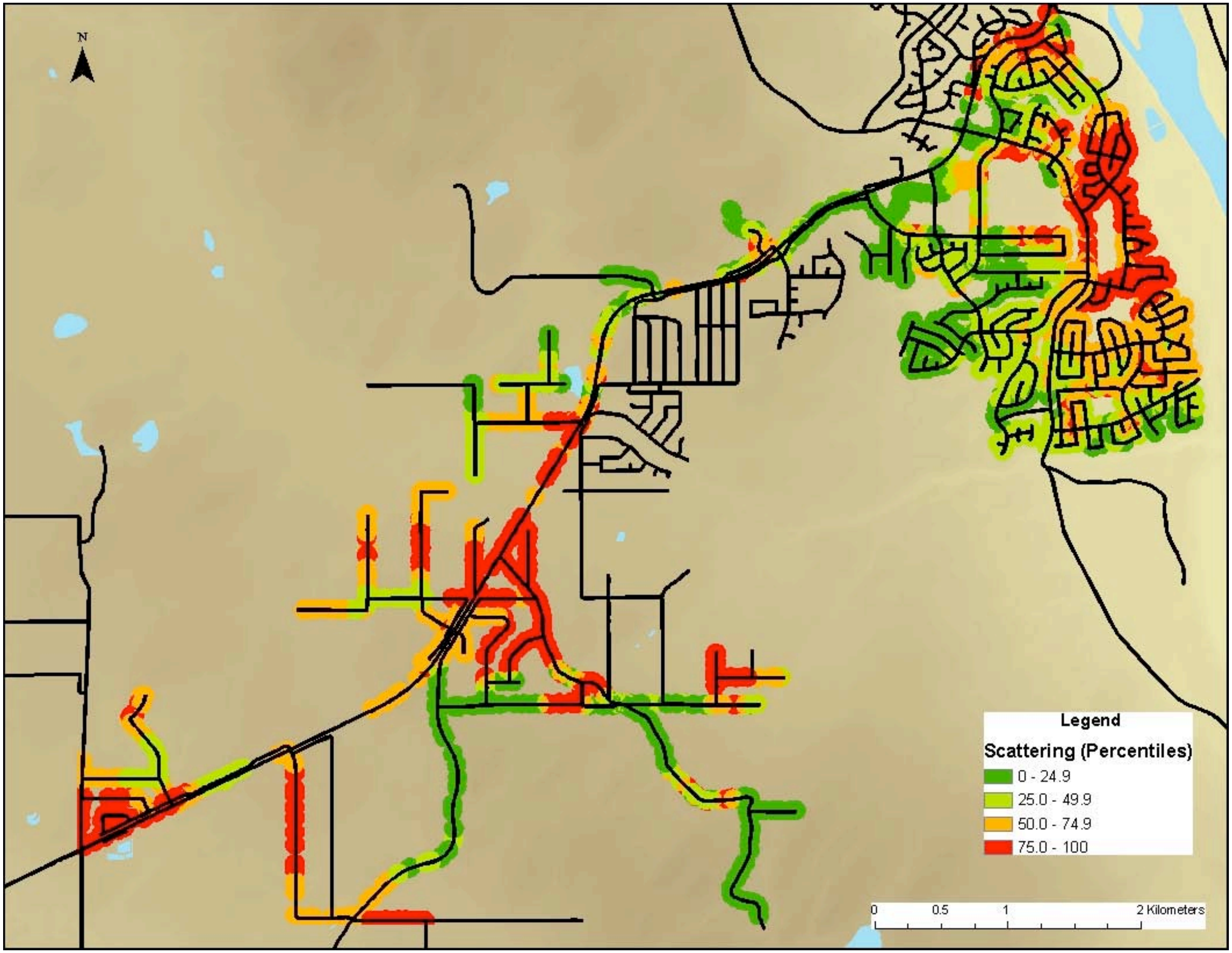

Figure 23: Smoothed Scattering Values (Percentile Form) for the College Heights Division of Prince George, January 27, 2010

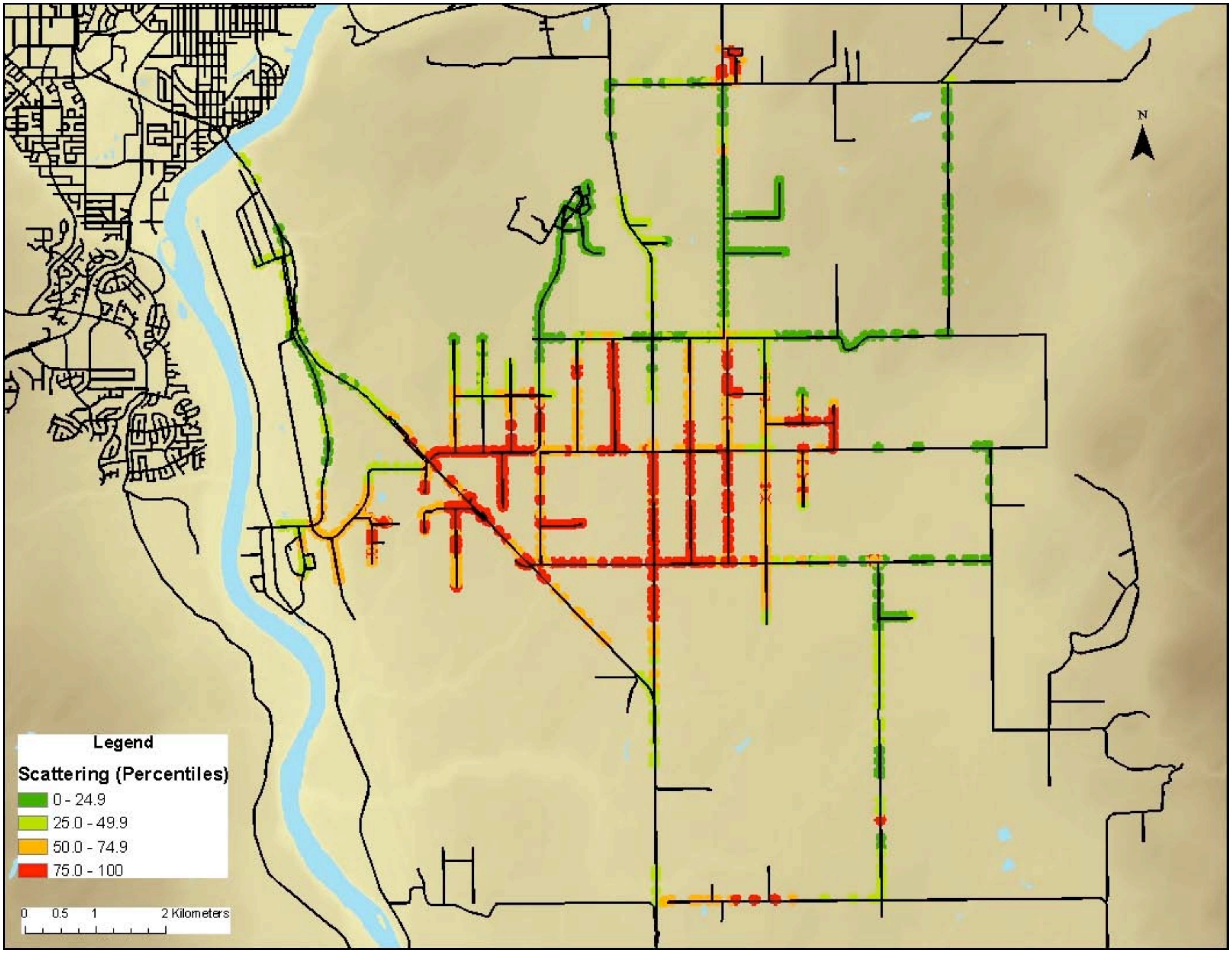

Figure 24: Smoothed Scattering Values (Percentile Form) for the Prince George East Division of Prince George, January 27, 2010

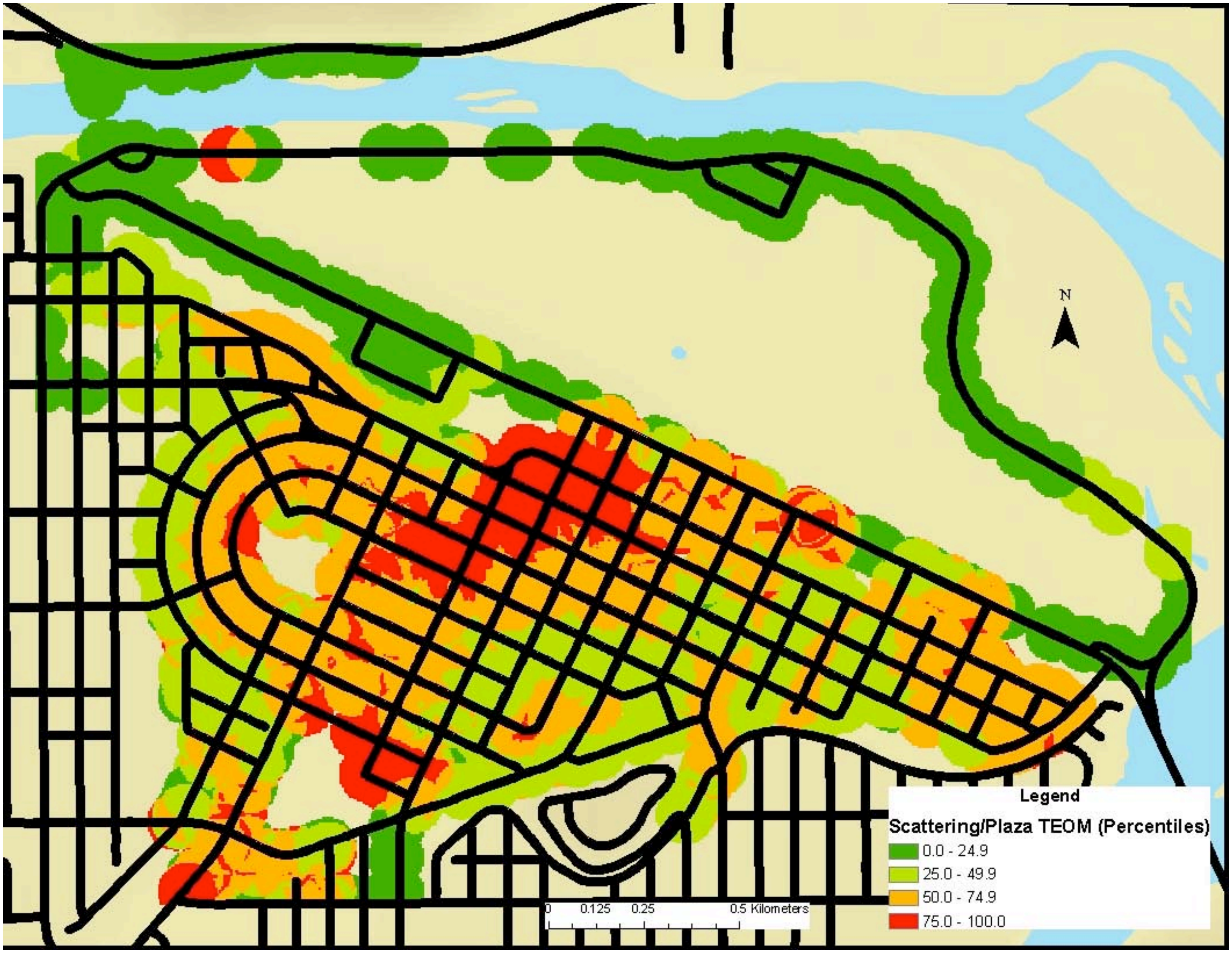

Figure 25: Smoothed Scattering Values (Percentile Form) for the Downtown Division of Prince George, February 2, 2010

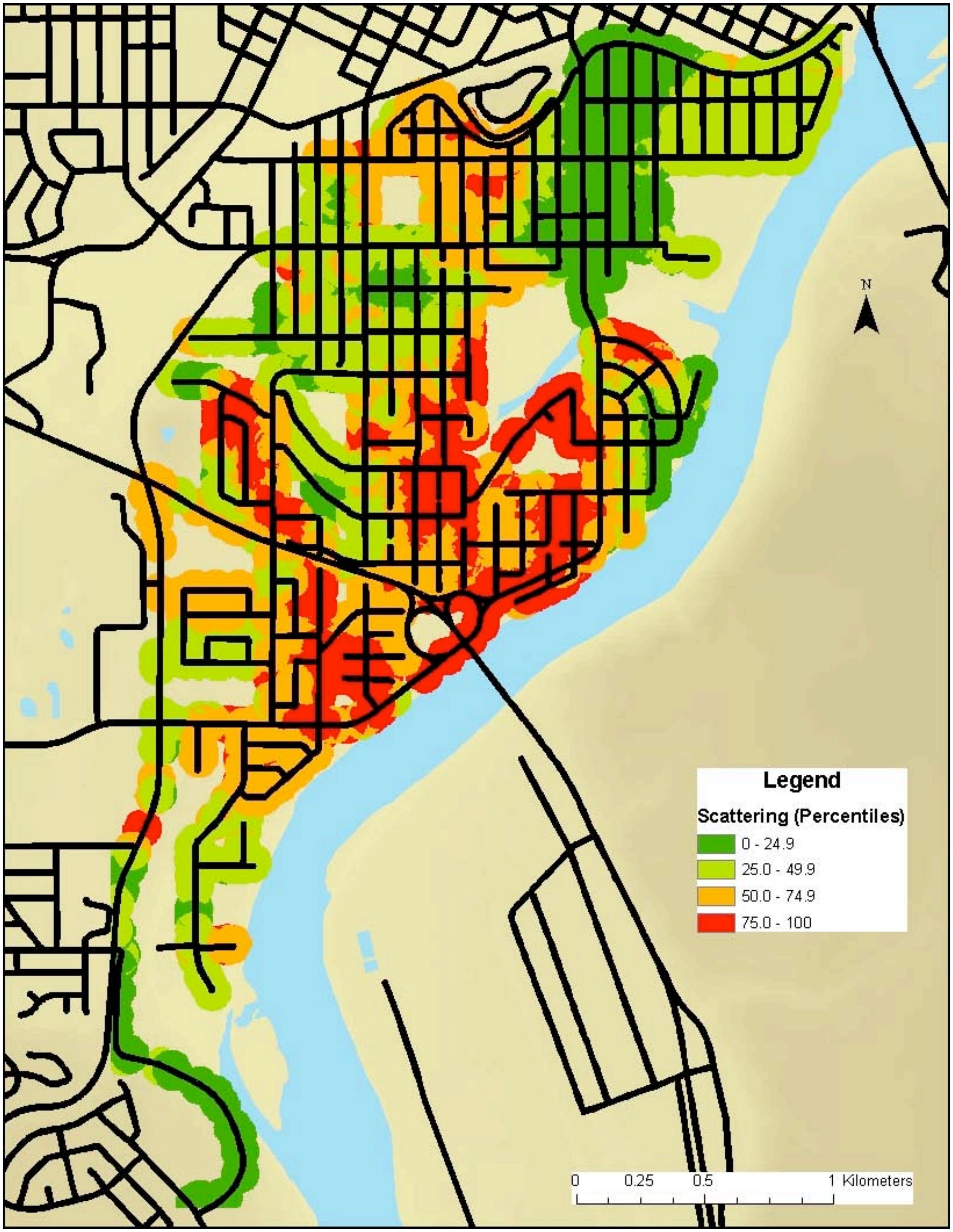

Figure 26: Smoothed Scattering Values (Percentile Form) for the South Fort George Division of Prince George, February 2, 2010

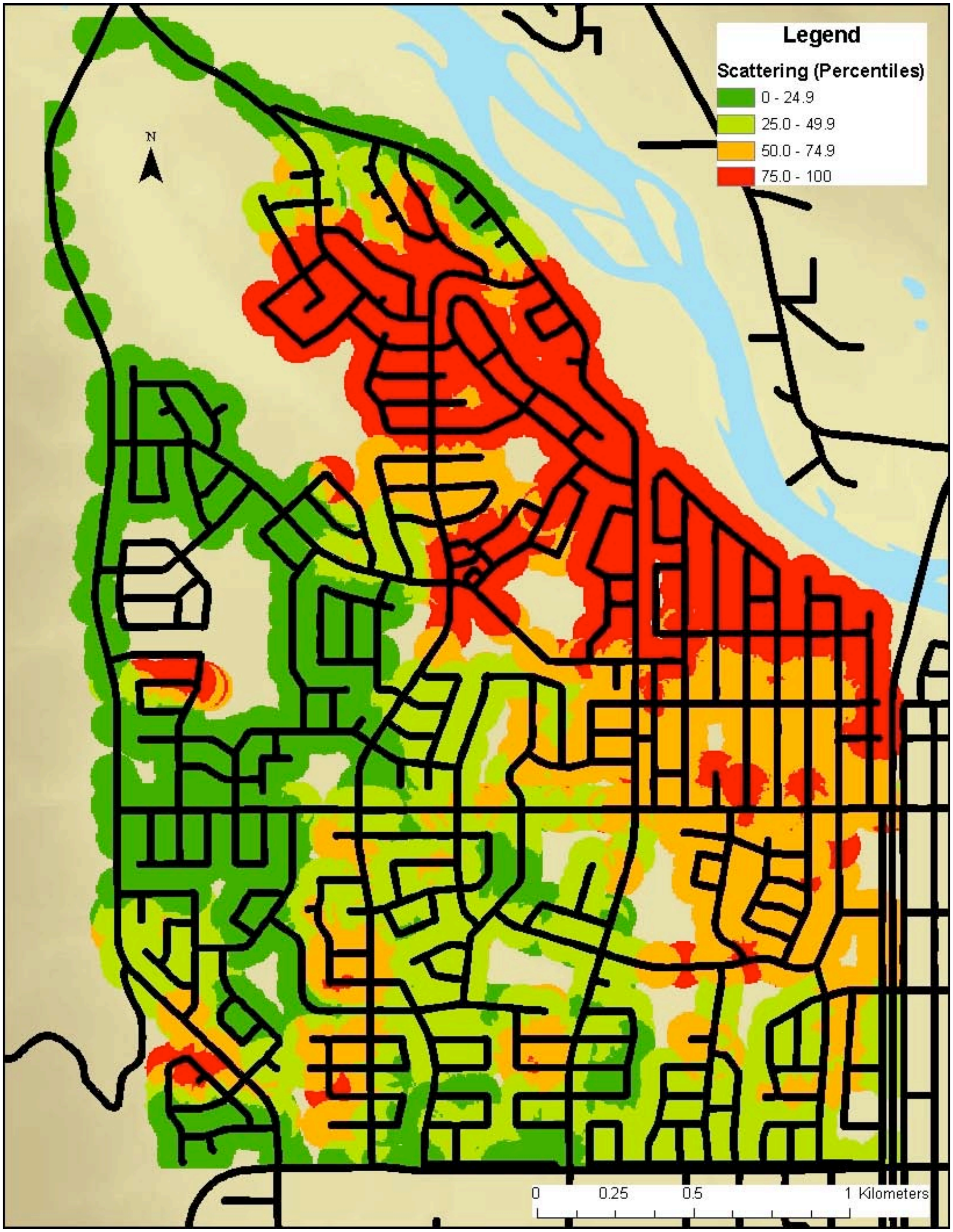

Figure 27: Smoothed Scattering Values (Percentile Form) for the Foothills Division of Prince George, February 6, 2010

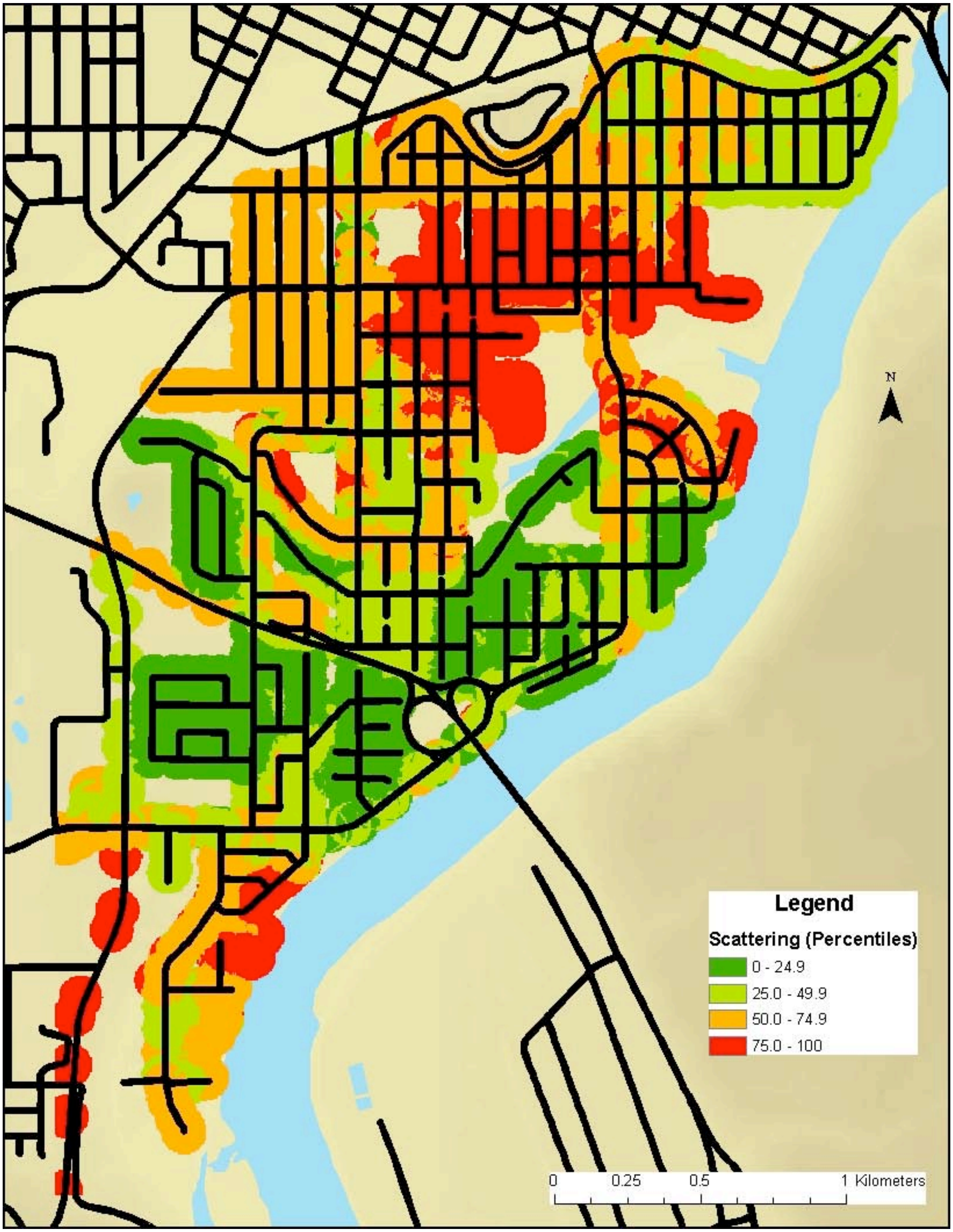

Figure 28: Smoothed Scattering Values (Percentile Form) for the South Fort George Division of Prince George, February 6, 2010

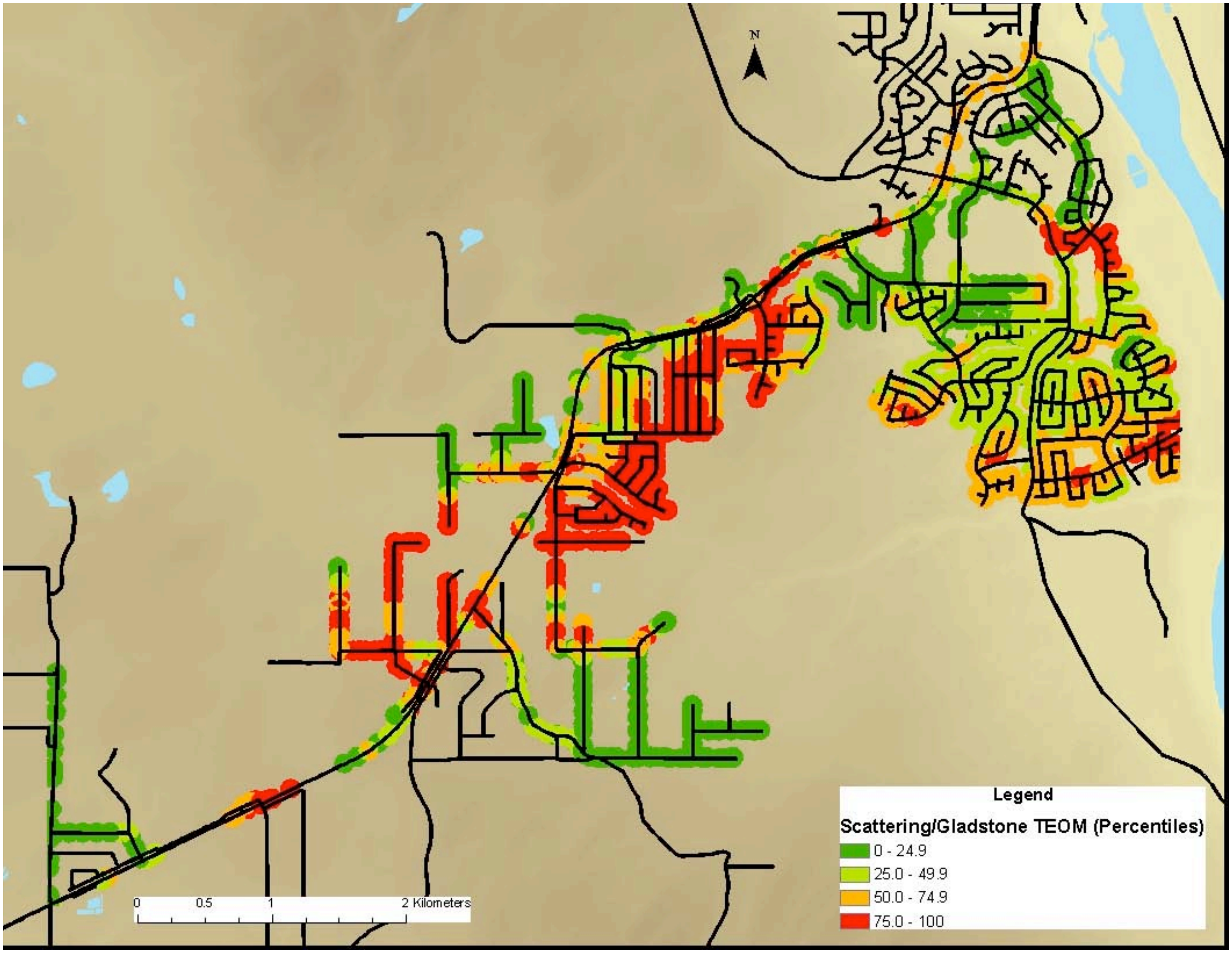

Figure 29: Smoothed Scattering Values (Percentile Form) for the College Heights Division of Prince George, February 7, 2010

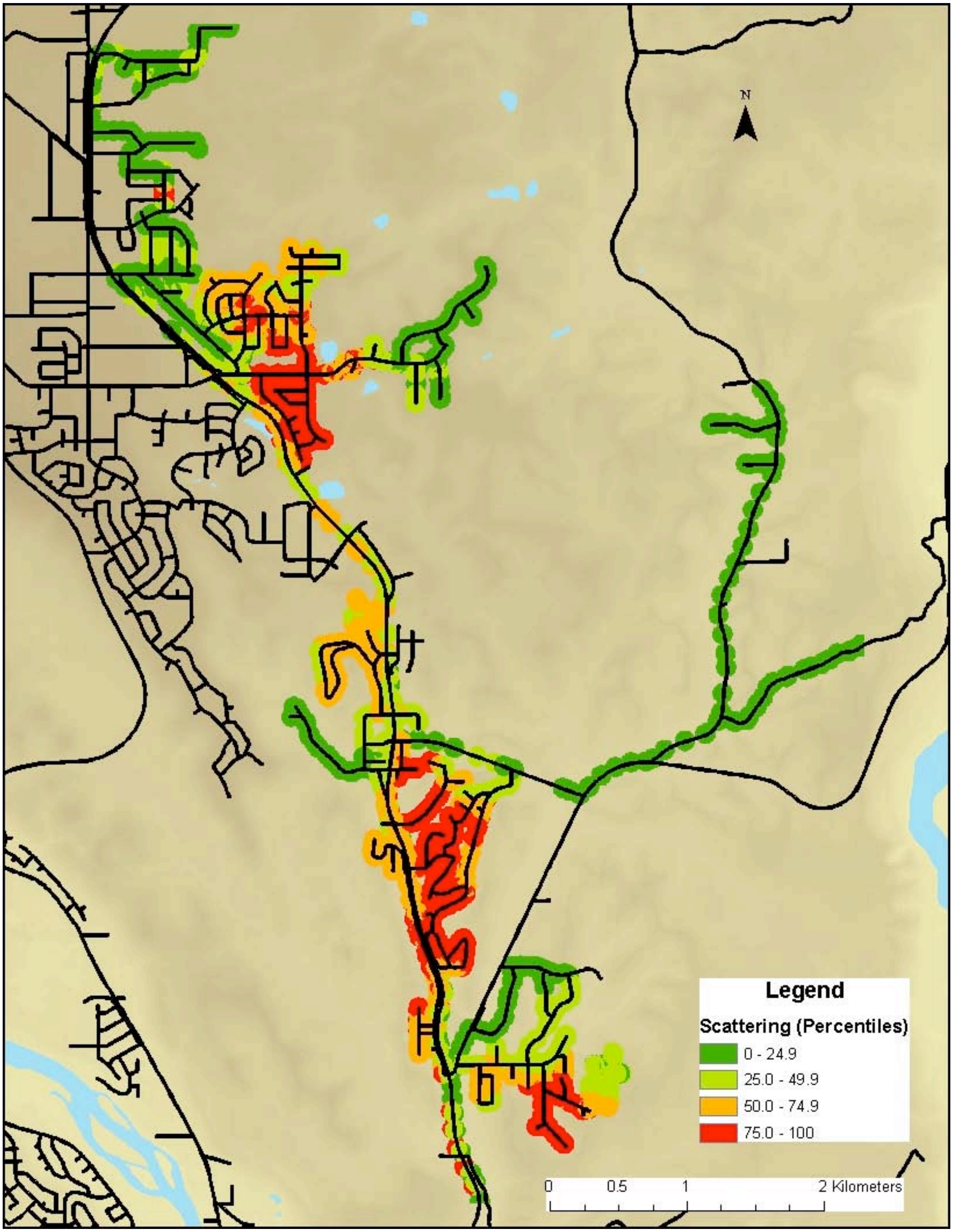

Figure 30: Smoothed Scattering Values (Percentile Form) for the Hart East Division of Prince George, February 7, 2010

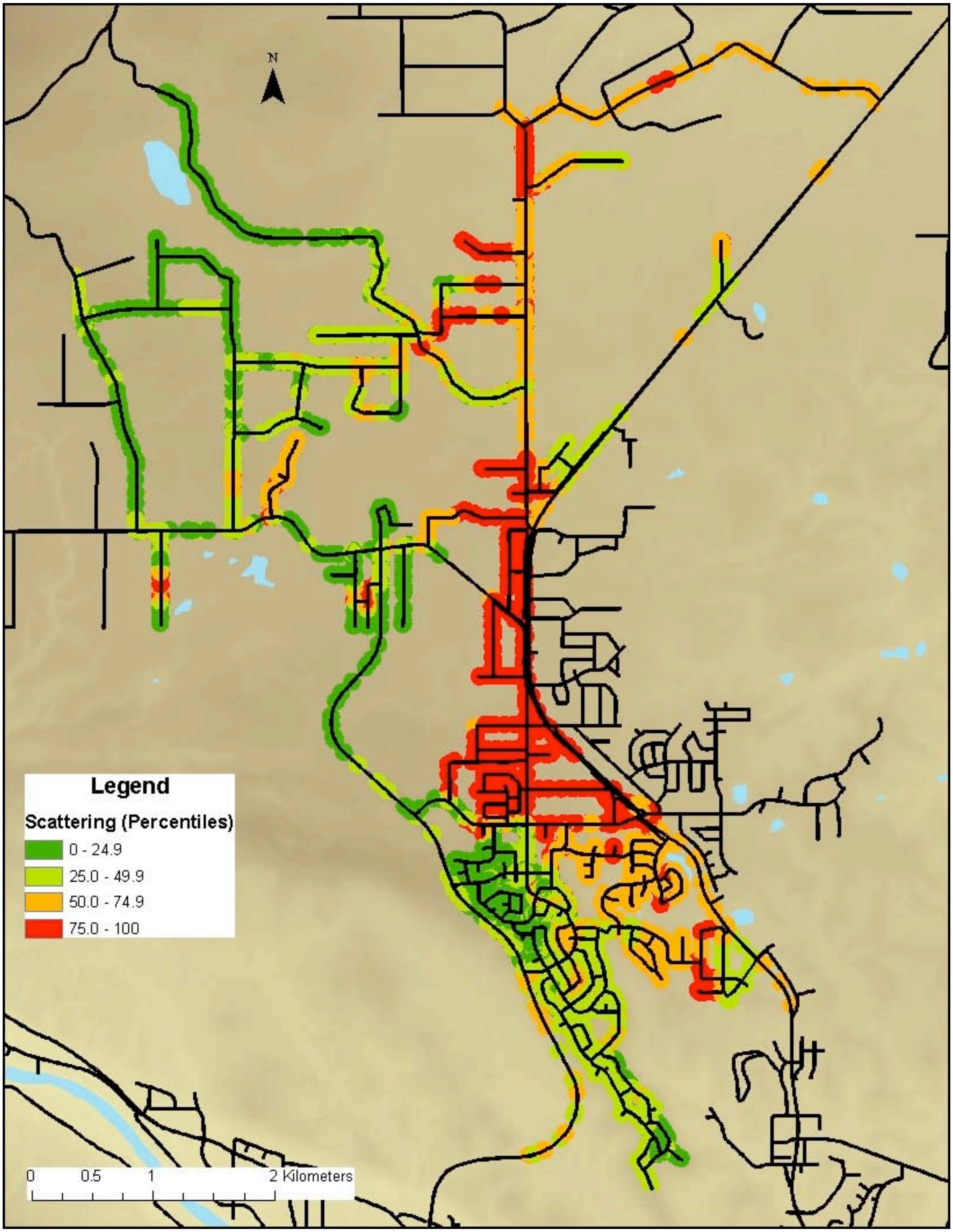

Figure 31: Smoothed Scattering Values (Percentile Form) for the Hart West Division of Prince George, February 8, 2010

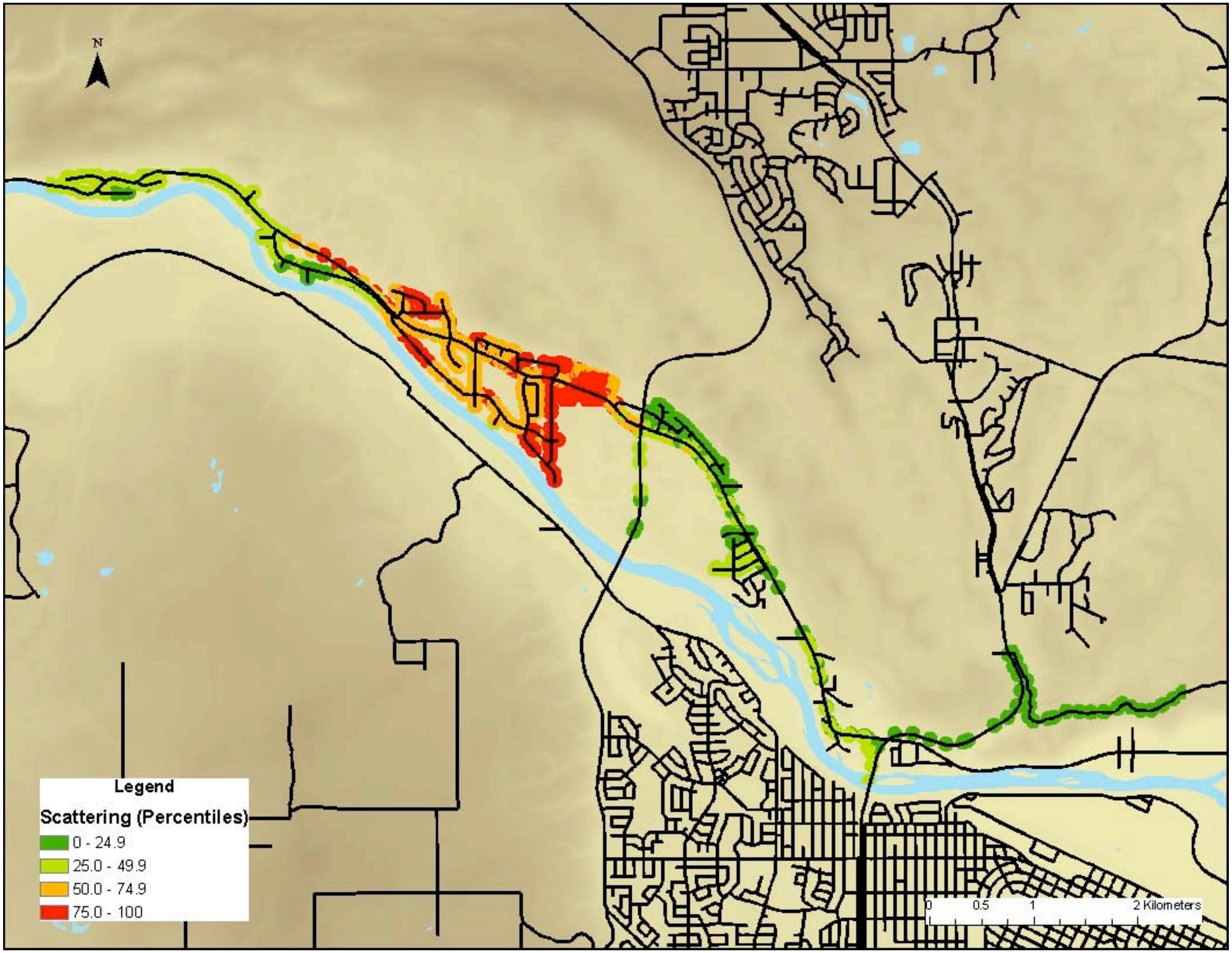

Figure 32: Smoothed Scattering Values (Percentile Form) for the North Nechako Division of Prince George, February 10, 2010

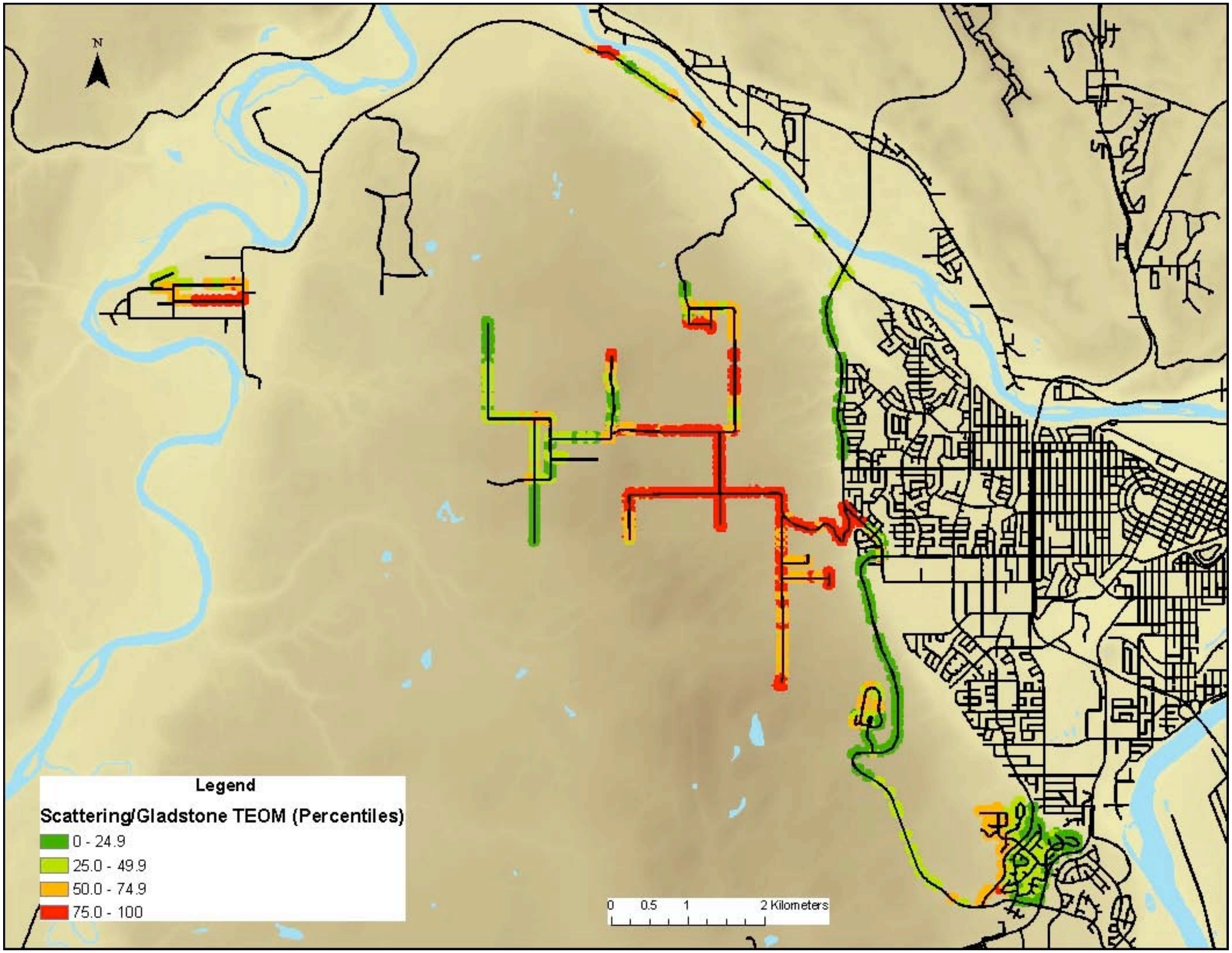

Figure 33: Smoothed Scattering Values (Percentile Form) for the Cranbrook Hill Division of Prince George, February 15, 2010

Figure 34: Smoothed Scattering Values (Percentile Form) for the Downtown Division of Prince George, February 15, 2010

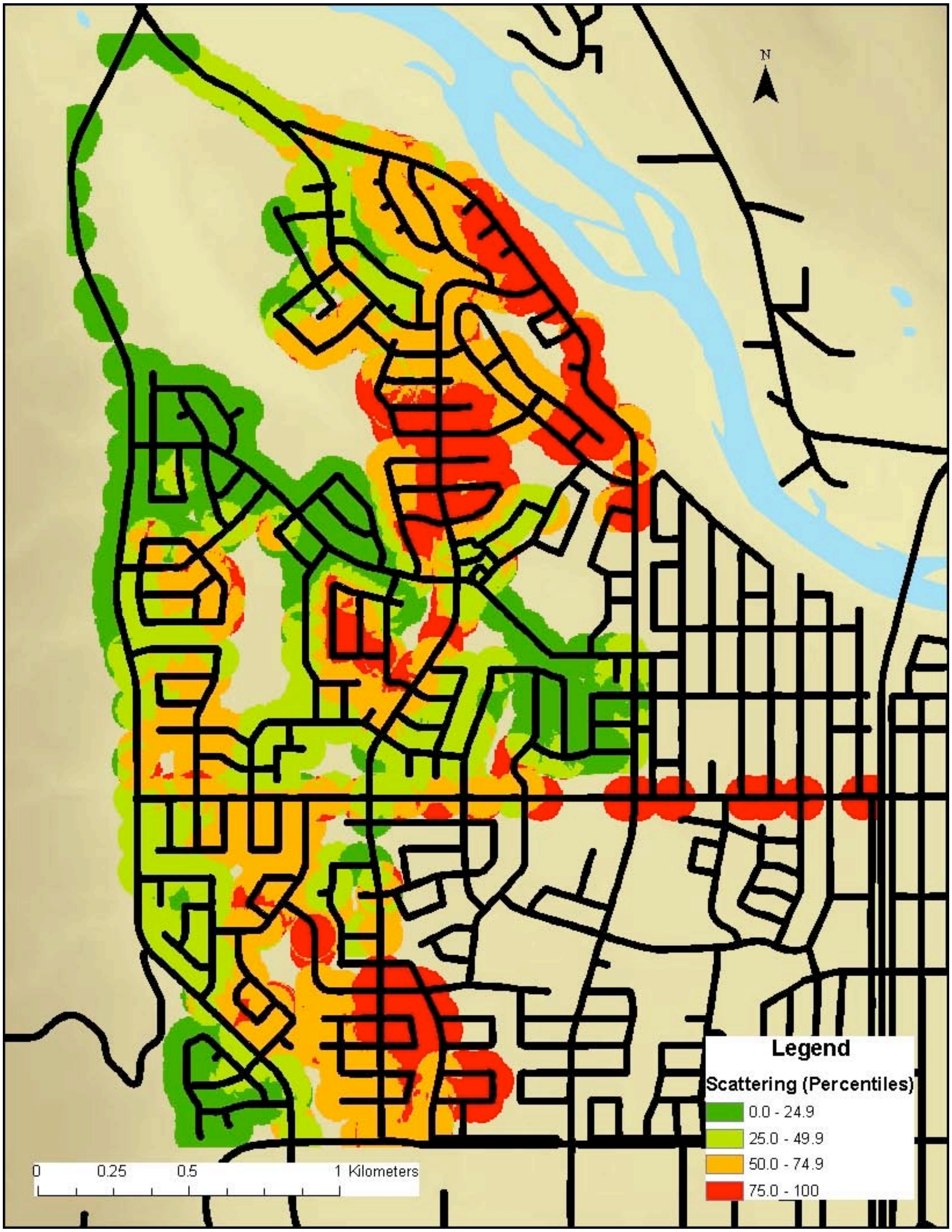

Figure 35: Smoothed Scattering Values (Percentile Form) for the Foothills Division of Prince George, February 17, 2010

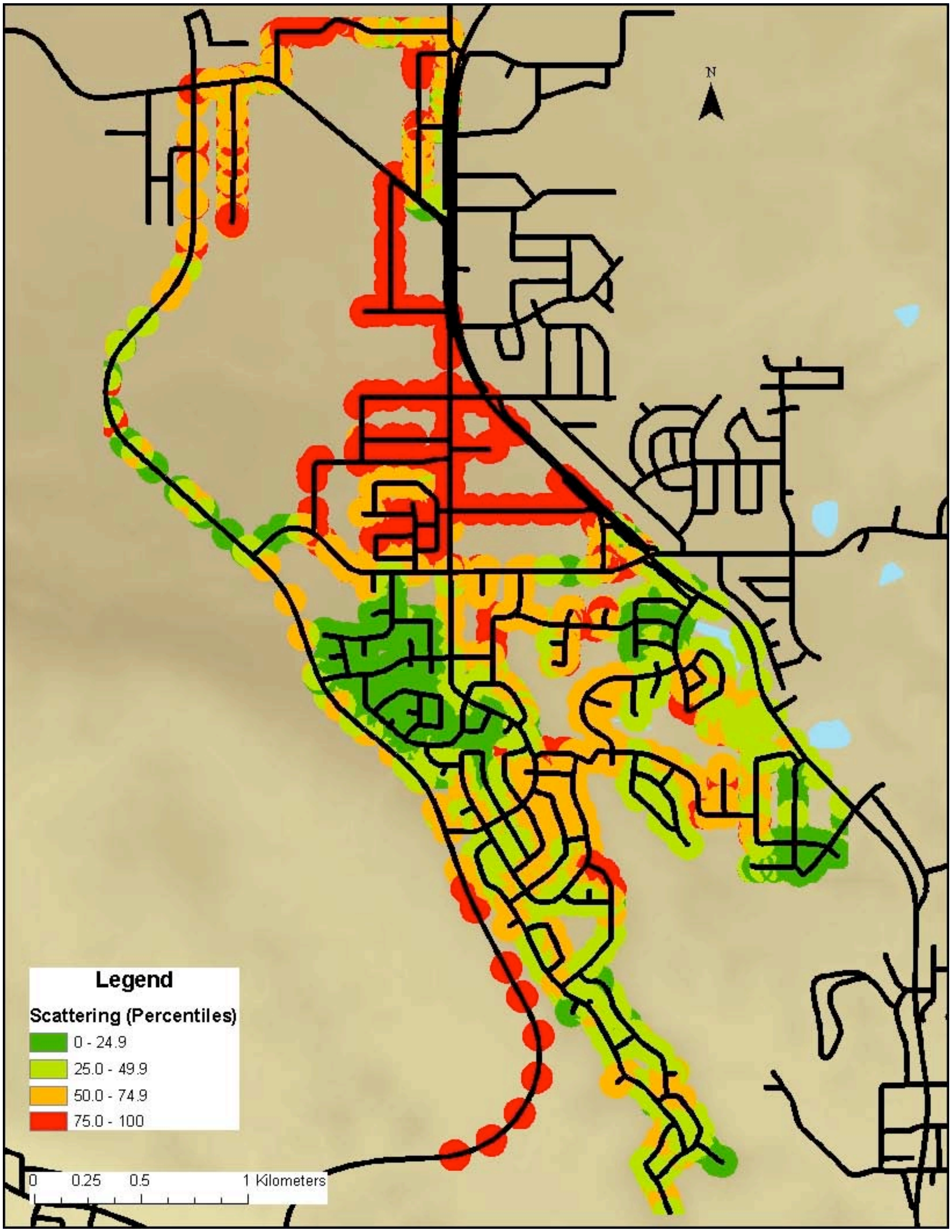

Figure 36: Smoothed Scattering Values (Percentile Form) for the Hart West Division of Prince George, February 20, 2010

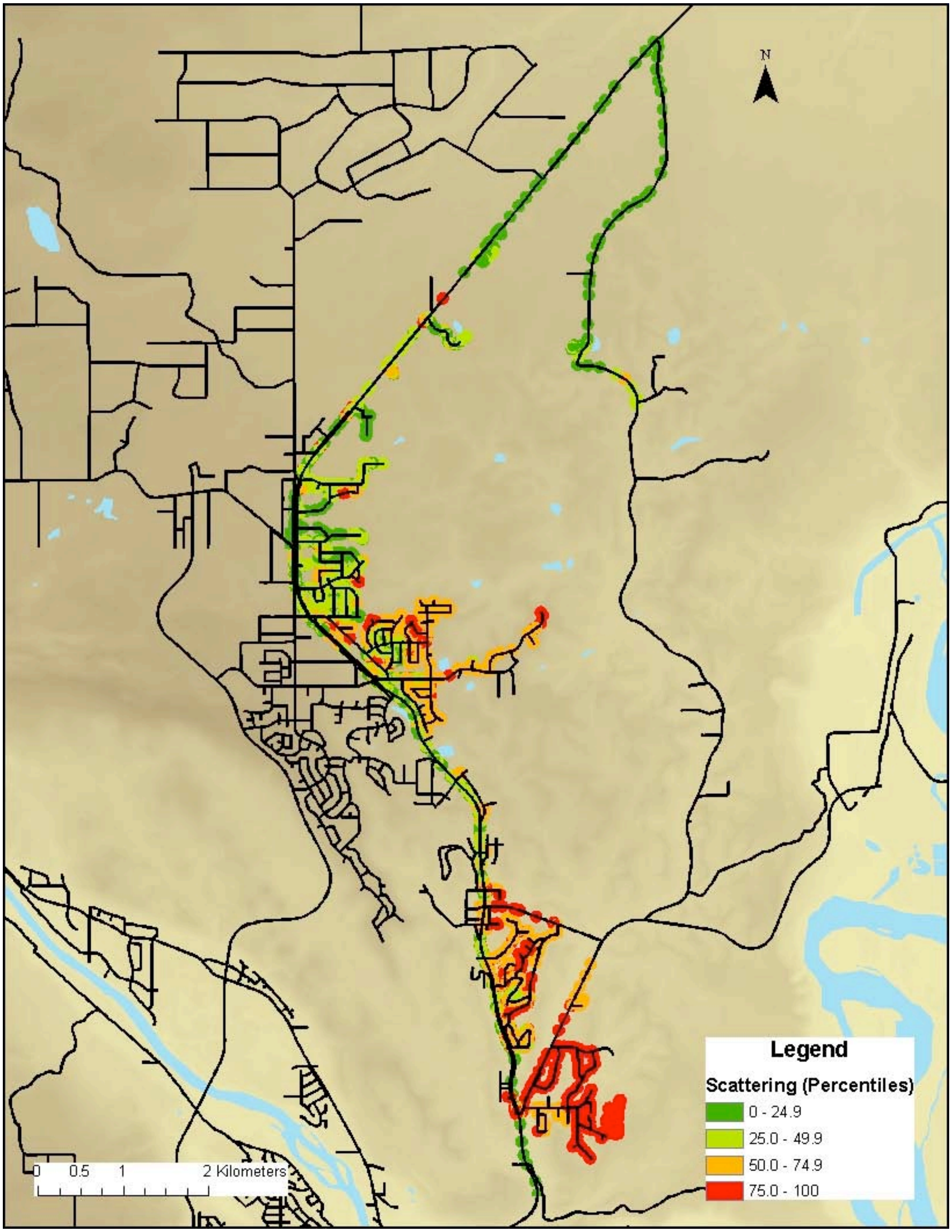

Figure 37: Smoothed Scattering Values (Percentile Form) for the Hart East Division of Prince George, February 21, 2010

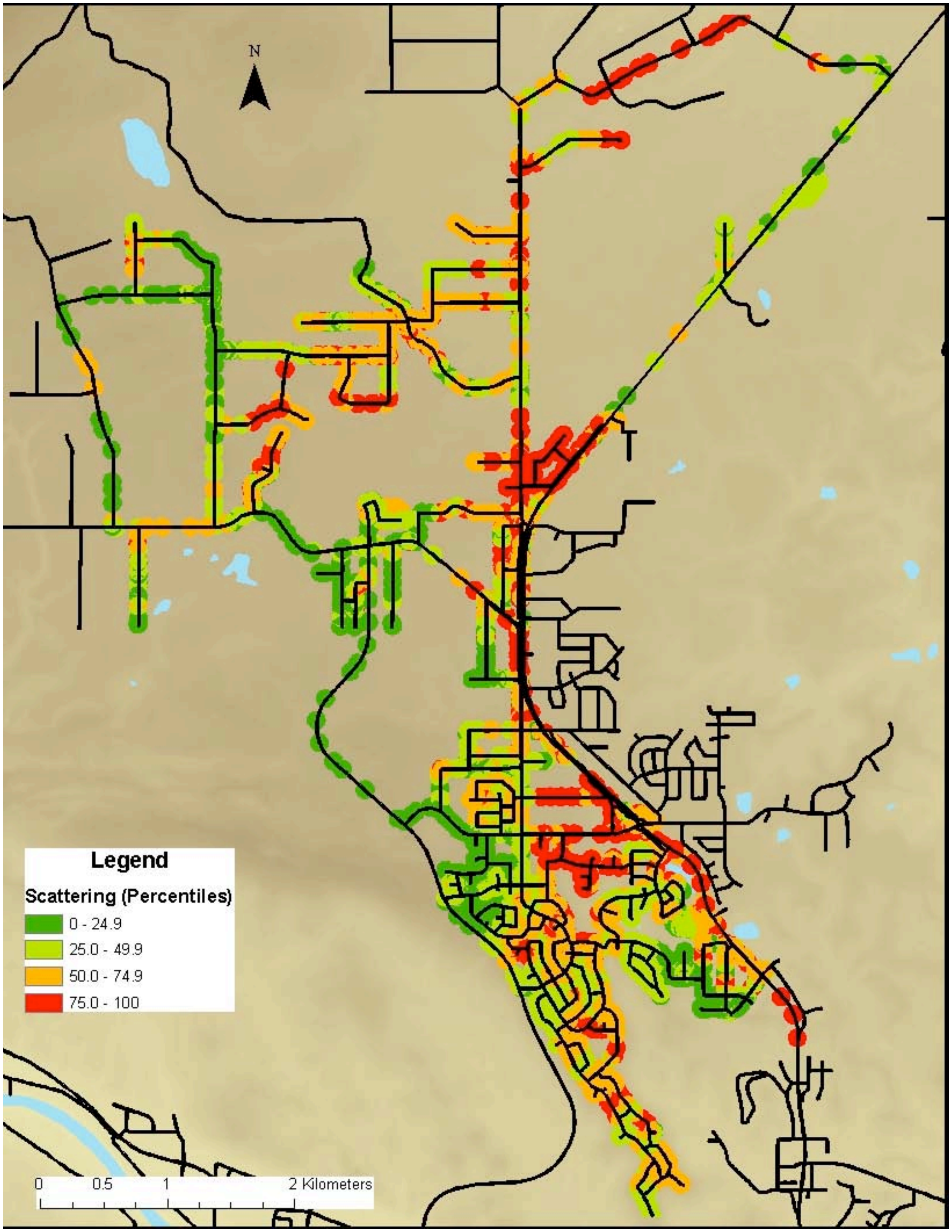

Figure 38: Smoothed Scattering Values (Percentile Form) for the Hart West Division of Prince George, February 27, 2010

8 DISCUSSION

Before analyzing our results, it is important to be aware of some of the challenges our study encountered and the sources of error these may have caused. In this section we also explore some of the strengths of our study.

8.1 Challenges Encountered throughout the Study

There were a number of challenges encountered throughout the project's execution. Most notably the following:

8.1.1 Meteorological Conditions

The meteorological conditions over the winter of 2009-2010 were not as prone to bad air quality as in previous winters. Table 4 gives a summary of the meteorological conditions for Winter 2010 and compares these conditions to the climate normals. Climate normals are the average conditions over the past 30 years. All meteorological and climatic data is from Environment Canada and was recorded at the Prince George Airport. Unlike concentrations of pollutants, meteorological variables tend not to vary extensively over a span of 10-20km. Therefore, meteorological data for the airport would be fairly accurate for all of Prince George.

The average temperatures for January, February and March were all above the climate normals by 4.2°C, 3.35°C and 2.5°C respectively. The winds were also above the normals by 1.4km/h, 3.9km/h and 2.2km/h for January, February and March respectively.

As can be expected with higher temperatures and winds, PM2.5 was below the 10 year average by 2.2 $\mu g/m^3$, 2.3 $\mu g/m^3$ and 2.5 $\mu g/m^3$ for January, February and March respectively. As the mobile monitoring study was looking to monitor on worst case scenario nights, this means for the study that on average either each night was not as ideal for monitoring or that there were less available nights for monitoring.

The second scenario, less available monitoring nights, seemed to be the case. Often there were weeks where high winds prevented monitoring from taking place. For example, between January 8 and January 22 there was not a single day where the forecast predicted sufficient monitoring conditions.

At the beginning of the study our plan was to have both nephelometers sample on 25-30 different nights therefore giving a total of 50-60 sets of samples. The scope of this plan was determined by evaluating PM2.5 levels in previous years.

The meteorology of the field season was the factor that had the largest effect on limiting the amount of sampling that could take place during the field season.

Table 4: Comparison of 2010 Weather to Climate Normals for Prince George(Meteorological and Climatic data from Environment Canada, Particulate Data from Ministry of Environment)

Temperature Normals (°C)	**JAN**	**FEB**	**MARCH**
Daily Average	-9.6	-5.4	-0.3
Standard Deviation	4.8	4.2	2.2
Temperatures for 2010 (°C)			
Daily Average	-5.54	-2.05	2
Wind Normals (km/h)			
Speed	9.9	10.5	10.1
Wind 2010 (km/h)			
Speed	11.3	6.6	13.3
PM2.5 - 10 year averages ($\mu g/m^3$)			
Plaza	10	11.8	7.8
Gladstone	N/A	N/A	N/A
PM2.5 2010 ($\mu g/m^3$)			
Plaza	7.8	9.5	5.3
Gladstone	7.2	9.1	3.5

8.1.2 Research Assistant Availability

In October of 2009 four research assistants were hired. Research assistants took turns between driving and giving directions and taking notes in the vehicle. All of these research assistants were UNBC students; three of them were at the undergraduate level and one of them was at the masters level. Because the original research assistants were students, research could not be the sole focus of their lives. Availability was difficult during the exam period throughout a good portion of December. Unfortunately, this coincided with the coldest period of the winter.

In early January, it was realized that more research assistants were needed to complete the amount of sampling desired. Six more research assistants were hired on an on-call basis. The majority of this group had natural science backgrounds and were currently unemployed. Their flexible schedules made it easier for them to stay out sampling later and put in long hours often on very short notice. Having unemployed graduates was helpful to get a lot of sampling completed. Had a larger amount of research assistants been deployed sooner we would have had a chance to get more sampling done. Not having enough research assistants employed at the beginning of the season was most likely the second largest factor in not getting all of the sampling we had wanted done.

Overall the research assistants showed dedication and interest in the study. There were never any no-shows and a great deal of the research assistants went above and beyond their duties in terms being available and having a flexible schedule.

8.1.3 Computer Issues

On February 22, one of the laptop computers used to collect nephelometer data crashed. Nephelometer data was backed up until January 27, 2010. Unfortunately, this meant that data was lost for quite a few nights for one out of the two nephelometers. This was an issue that could have been avoided and teaches the lesson that with this type of study, data should be backed up every single night.

8.1.4 Equipment Malfunction

These nephelometers were borrowed from the School of Environmental Health at UBC. The nephelometers were several years old.

There were a number of technical issues that arose during the field season with the nephelometers. The pump on nephelometer B broke. Because the nephelometer was still producing what seemed like reasonable readings the issue was only noticed after it had been taken into the field on the following dates and routes: February 6/7, 2010 in South Fort George, February 10/11, 2010 in North Nechako, February 20/21 in Hart East and February 21/22 in Hart West. Data from Hart East on February 20/21 and Hart West on February 21/22 was not used. Data from the other nights listed is still presented in Section 7 but not felt to have the same quality as the data from other monitoring nights.

The correlation between the two nephelometers was not reliable (see Appendix J). Because this quality assurance procedure did not produce sufficient results we were more cautious with the data. Because of the uncertainty, we decided to display the data in 4 quantiles rather than in terms of scattering values.

The nephelometer vs. TEOM relationships tended to be variable (see Appendix J). Because of the inconsistency in the relationship we stayed away from translating scattering values into concentrations of particulate matter as originally intended.

Not surprisingly, the nephelometers did not always pass calibrations, span measures, zero adjusts, span checks and zero checks all of the time. Often zero measurements were negative numbers. Ecotech, the manufacturer of the nephelometers, determined that the light source on nephelometer B was most likely not functioning properly. They also determined that there may have been an issue with one or both of the temperature sensors. Ecotech believed that the temperature of the light cell may have a significant impact on sample readings in high moisture environments such as the one we were sampling in for woodsmoke.

The nephelometers were shipped from Vancouver to Prince George for the research. Nephelometers are being continuously handled during this type of study; brought from inside down stairwells and placed in the vehicle, and back at the end of the sampling night. Shipping as well as constant handling could have caused small parts to come loose inside and led to some of the instrument malfunction issues encountered.

Another instrument issue often encountered was the GPS falling out of the cigarette lighter. At the beginning of our study this happened a lot. The research assistant giving directions had to keep a very close eye on this which was difficult to maintain. A little bit into the field season we realized that the metal could be bent slightly on the end of the GPS that rests in the cigarette lighter to keep the GPS in more securely.

8.1.5 Levoglucosen Sampling

Originally one of the intents for this project was to measure levoglucosan, a tracer for woodsmoke. Partisols were set up on the roof of several schools in Prince George, however in the end funding was secured too late in the season for levoglucosan sampling to take place.

8.1.6 Sampling Routes Chosen

The sampling routes we chose to use went down every single street in Prince George and incorporated even some streets outside city boundaries. At the time the study was being planned it was thought that there was a strong advantage to making sure as many every streets as possible were sampled. We did not want to miss a single "hotspot". The maps, however, seem to show mainly large areas of similar values which may mean that we could have gotten the overall pattern from sampling only every second or third street. This would have allowed us to increase the number of times we sampled each division which would have presumably increased our confidence in the results.

8.1.7 Study Area

Our study area, the City of Prince George was approximately 30km by 40km. Although mobile monitoring is often executed on much large scales in much larger cities (Larson, 2007), the large size of Prince George relative to smaller towns where mobile monitoring is also performed makes using TEOM data for adjustments more questionable. Using TEOM data to adjust nephelometer data is also made more complicated by the fact that Prince George has numerous sources of air pollution which affect different parts of the city to different extents.

8.2 Strengths of Our Study

Although we did encounter some difficulties, there were advantages to our study as well. We were firstly, lucky to have two TEOMS to use to average data. In other studies (Millar, 2008) only one TEOM was present in each town. Also, the TEOM averaging method we used which is detailed in section 6.4.1 is thought to be a strong and novel method to adjust data.

8.3 Sampling Analysis

As discussed above we were not able to repeat each division as often as we would have liked (5-6 times for each division). Table 5 shows how many different nights each of the divisions were sampled.

Table 5: Repeatability of Sampling in Prince George's Divisions

ROUTE/ DIVISION	NAME OF ROUTE	NUMBER OF TIMES SAMPLED
1	Hart Highway West	4
2	Hart Highway East	3
3	North Nechako	1.5
4	Prince George East	1
5	College Heights	3
6	Cranbrook Hill	1
7	Foothills	2.5
8	Central Fort George	1
9	Downtown	3
10	South Fort George	3
11	Westwood	2

8.3.1 Hart West

Table 6 gives a summary of information on sampling in the Hart West Division. Three different starting points were used. Starting times were generally about the same except for February 20 where some equipment issues didn't allow for the usual start time. Start times describe the time where sampling started and not the time where the research assistants showed up and began assembling the equipment. Figures which describe Hart West are numbers 19, 31, 36 & 38 all in Section 7. Sampling results from February 8, 20 & 27 all seem to show similarities in the positioning in "hot spots" despite the fact they have different starting points and start times.

Table 6: Summary of Sampling in the Hart West Division

Night	Start #	Start Time	Results Adjusted by TEOM?
Jan 23 2010	2	6:30pm	No
Feb 8 2010	3	6:00pm	No
Feb 20 2010	1	10:00pm	No
Feb 27 2010	1	7:00pm	No

8.3.2 Hart East

Table 7 gives a summary of the Hart East Division. Figures for Hart East are numbers 17, 30 and 37 in the Results Section. The results for February 2 and 7 look somewhat alike with the highest levels found mainly in the southern area. The non-adjusted results for January 8 (Figure I -17) is more similar to the two nights in February. It is debatable to whether these non-adjusted results can be considered the most realistic results for January 8.

Table 7: Summary of Sampling in the Hart East Division

Night	Start #	Start Time	Results Adjusted by TEOM?
Jan 8 2010	1	7:00pm	Gladstone TEOM
Feb 7 2010	4	6:00pm	No
Feb 21 2010	1	6:30pm	No

8.3.3. North Nechako

North Nechako was sampled on two separate nights. See summary on sampling data in Table 8 as well as Figures 16 and 32. The two figures show similar results.

Table 8 : Summary of Sampling in the North Nechako Division

Night	Start #	Start Time	Results Adjusted by TEOM?
Jan 7 2010	1	6:30pm	No
Feb 10 2010	3	7:00pm	No

8.3.4 Prince George East

Prince George East was only sampled once. See Table 9 as well as Figure 24.

Table 9: Summary of Sampling in the Prince George East Division

Night	Start #	Start Time	Results Adjusted by TEOM?

Jan 27 2010	1	8:30pm	No

8.3.5 College Heights

College Heights was sampled three times. See summary in Table 8. It looks like there are similarities between the three nights. On all three nights there are high values in the center east part of the division. Near the center, to the south of Highway 16 there is a large area of high values as well.

Table 10: Summary of Sampling in the College Heights Division

Night	Start #	Start Time	Results Adjusted by TEOM?
January 23, 2010	1	6:30pm	No
January 27, 2010	1	6:30pm	No
February 7, 2010	3	6:30pm	Gladstone TEOM

8.3.6 Cranbrook Hill

The Cranbrook Hill Division of Prince George was sampled once. See Figure 33 and Table 11.

Table 11: Summary of Sampling in the Cranbrook Hill Division

Night	Start #	Start Time	Results Adjusted by TEOM?
February 15, 2010	1	6:30pm	Yes, by Gladstone

8.3.7 Foothills

Foothills was monitored three times. See Table 12 and Figures 13, 27 and 35. Unfortunately the entire route was only completed on one of the three nights. Foothills was a very long route which was hard to do in an entire night. There seems to be some similarities between evenings. Both nights show high values in the right top. The left side of the Division tends to have low values on December 9 and February 6 and medium values on February 17.

Table 12: Summary of Sampling in the Foothills Division

Night	Start #	Start Time	Results Adjusted by TEOM?
December 9, 2009	1	6:30pm	No
February 6, 2010	3	7:00pm	No
February 17, 2010	5	6:30pm	No

8.3.8 Central Fort George

Central Fort George was monitored several times but unfortunately some of the data was lost when the computer crashed. See Figure 18 and Table 13 for the information on the remaining sampling date.

Table 13: Summary of Sampling in Central Fort George

Night	Start #	Start Time	Results Adjusted by TEOM?
January 22, 2010	1	7:30pm	No

8.3.9 Downtown

Downtown Prince George was monitored completely twice and a third time only the residential area of Downtown was monitored (February 15, 2010).

Table 14: Summary of Sampling in Downtown Prince George

Night	Start #	Start Time	Results Adjusted by TEOM?
January 3, 2010	1	7:30pm	No
February 2, 2010	3	6:30pm	No
February 6, 2010	2	6:30pm	No

8.3.10 South Fort George

A summary of information for South Fort George is available in Table 9. The Figures for South Fort George are numbers 14, 26 and 28. Results for January 3 and February 6 tend to be more similar than February 2. The three figures do not seem to show resemblance. We expected that the results for January 3 may not follow the typical pattern because PM measurements at Gladstone & Plaza were not terribly high. On February 6 Nephelometer B was used with the broken pump therefore we would expect that these results were not ideal as well and that the results for February 2 have the most chances of showing a typical high PM night.

Table 15: Summary of Sampling in the South Fort George Division

Night	Start #	Start Time	Results Adjusted by TEOM?
January 3, 2010	1	7:30pm	No
February 2, 2010	3	6:30pm	No
February 6, 2010	2	6:30pm	No

8.3.11 Westwood

The two figures showing sampling results in Westwood are Figure 15 and 22. Table 16 also describes sampling in Westwood. The two nights show fairly different results. This may be due to the fact that January 26th was not an ideal monitoring night with PM levels at both sites below 10μg/m^3 the entire night.

Table 16: Summary of Sampling in the Westwood Division

Night	Start #	Start Time	Results Adjusted by TEOM?
January 6, 2010	1	6:30pm	No

January 26, 2010	5	6:30pm	No

8.4 Times of Highest Concentrations & Sizes of Hotspots

Our results seem to show that the time of highest concentrations throughout a night seem to vary greatly. Often the pattern on a particular night is very random with times of elevated concentrations being seemingly randomly distributed. See graphs in Appendix H.

The size of hotspots also seems to be randomly distributed. The graphs in Appendix H show comparatively high values randomly distributed with these high values lasting any amount of time: from as low as a few minutes to as high as several hours.

9 CONCLUSIONS

This study provided an initial look at the woodsmoke distribution in Prince George. Despite encountering significant challenges, many lessons were learned which may provide insight to future mobile monitoring studies (Section 8.1).

To address the project objectives and rationale:

1. **To assess neighbourhood exposure of $PM_{2.5}$ from residential wood burning, to identify whether and to what extent there are significant, localized wood smoke "hotspots" (i.e. persistent elevated wood smoke concentrations) in neighbourhoods**

We were somewhat successful in finding localized "hotspots". The divisions sampled the most often; College Heights, Hart East and Hart West all seemed to show some consistent "hot spots". Our study was a good start however, more sampling may be necessary to confirm these hot spots.

In areas we only had the chance to monitor one time it is impossible to comment on whether elevated areas are indeed hotspots or whether these divisions do display a consistent ambient pattern. Divisions we only have one set of results for are Cranbrook Hill and Prince George East.

2. **To assess neighborhood exposure of $PM_{2.5}$ from residential wood burning, to determine whether and to what extent wood smoke is a significant contributor to $PM_{2.5}$ levels in Prince George**

Unfortunately, the results from this study do not allow us to comment on neighborhood exposure of $PM_{2.5}$ from residential wood burning because the relationship between the nephelometers and TEOMs were not constant.

It is difficult to comment on whether and to what extent woodsmoke is a significant contributor to $PM_{2.5}$ levels in Prince George because we were not able to convert scattering values to PM2.5.

3. **To assess population exposure in wood smoke hotspots so to determine vulnerability and highlight priority neighborhoods**

Health outcome data for Prince George will be assessed with the wood smoke data to determine whether a correlation exists and how strong this correlation is.

These health outcome findings will be submitted as a separate report.

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Project Team

1. Tom Kosatsky, MD, MPH, Associate Director, Environmental Health Services Division, BC Centre for Disease Control

2. Ray Copes, BA (Hon), B.Sc., MD, CM, M.Sc., Director, Environmental Health Services Division, BC Centre for Disease Control

3. Catherine Elliott, B.Sc., MD, CCFP, M.HSc., Environmental Health Services Division, BC Centre for Disease Control,

4. Peter Jackson, Ph.D., Professor of Atmospheric Science, Office: 8-434 Environmental Science and Engineering Programs, UNBC

5. Gail Millar, B.Sc., Master's Student in Natural Science Studies, UNBC (rothg@unbc.ca)

6. Mellissa Winfield-Lesk, M.Sc., P.Ag., Section Head,

7. Daniela Fisher, B.Sc., LL.B., Air Quality Management Co-ordinator, Prince George Air Improvement Roundtable

8. Prabjit Barn, M.Sc., Environmental Health Scientist, Environmental Health Division, BC Centre for Disease Control

9. William Osei, MD, M.P.H., Medical Health Officer, Northern Health Authority. Northern Health Authority
   4th Floor – 1600 Third Avenue
   Prince George, BC V2L 3G6

10. David Bowering, MD, MHSc., Chief Medical Health Officer, Northern Health Authority Corporate Headquarters
    600 – 299 Victoria Street Prince George BC V2L 5B8

11. Dennis Fudge, Meteorologist, Ministry of Environment, Prince George. Plaza 400, 4th Avenue

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