2012-2013 Winter Monitoring Study

Using Nephelometers to assess Fine Particulates in King and Pierce Counties

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Puget Sound Clean Air Agency

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Technical Report

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Acknowledgements and Contact

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The Washington State Department of Ecology monitoring staff provided data and quality assurance support for the fixed sites involved with this study. Doug Knowlton of Ecology provided some shelters used at the temporary sites. The Puyallup Tribe operated the fixed site at the Puyallup 66th Avenue station. Thank you.

We also would like to thank those who provided valuable comments to the draft report.

For your questions, please contact Matt Harper at (206) 689-4009, matth@pscleanair.org.

Executive Summary

The Puget Sound Clean Air Agency recently completed a winter monitoring study to better characterize pollution levels in parts of South King County and Pierce County. The Agency monitored fine particulate pollution (PM 2.5), which is a complex mixture of extremely small particles and liquid droplets that are 2.5 micrometers in diameter and smaller[1]. PM 2.5 degrades air quality and visibility, and is linked to health effects such as premature death, heart attacks, aggravated asthma, and decreased respiratory function[2].

The Agency monitors PM 2.5 throughout Puget Sound, but has not recently monitored in parts of King and Pierce County. This monitoring study helped the Agency understand PM 2.5 levels to better assess the reach of our current monitoring network, inform burn ban forecasts, and assess model performance.

Historical data has shown that PM 2.5 levels are highest during the winter months, when strong inversions typically occur. The Puget Sound Clean Air Agency used temporary samplers to characterize air quality patterns in King and Pierce County from November 2012 to February 2013.

The Agency collected data at each of these monitoring stations with a nephelometer. The nephelometer measures light scattering, which is commonly used in Washington as a surrogate to estimate fine particulate matter (PM 2.5) concentration. The data collected is non-regulatory in nature, but is useful for characterizing high pollution days when a temperature inversion traps concentrated PM 2.5.

The Agency collected data at nine temporary monitoring sites. Three temporary sites were located in King County. Six temporary sites were located in Pierce County. Temporary monitoring sites are subject to more variation than fixed monitoring sites. The operators attempted to limit the effects of this variation by controlling for site scale, site temperature fluctuations, and variation in instrument calibrations. The data quality was acceptable at 8 of the 9 temporary sites. The Bonney Lake monitor was eliminated from the analysis because of poor data quality.

The fixed monitoring sites used in this study included one site in King County, four in Pierce County, and one in Kitsap County. All monitoring sites are mapped on Figure 1 (fixed in orange, temporary in green).

[1] http://www.epa.gov/pm/
[2] http://www.epa.gov/pm/health.html

Figure 1. Monitoring Sites Evaluated.

Since there were nine temporary sites and only six nephelometers available for the study period, the Agency operated some temporary sites during the first half of the wood smoke season, and then moved those sites to other temporary locations during the second half of the wood smoke season. Two distinct time periods were analyzed.

Figure 2 (below) shows estimated PM 2.5 concentration Mean and Variability of the 8 highest days during the first of the two time periods. King County sites are listed on the left, Pierce county sites are listed in the center and on the right. We chose the 8 highest days to display for some level of consistency with the value that is used to compare to the daily health-based national ambient air quality standard (NAAQS). More information about the PM 2.5 standard can be obtained at this link. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html

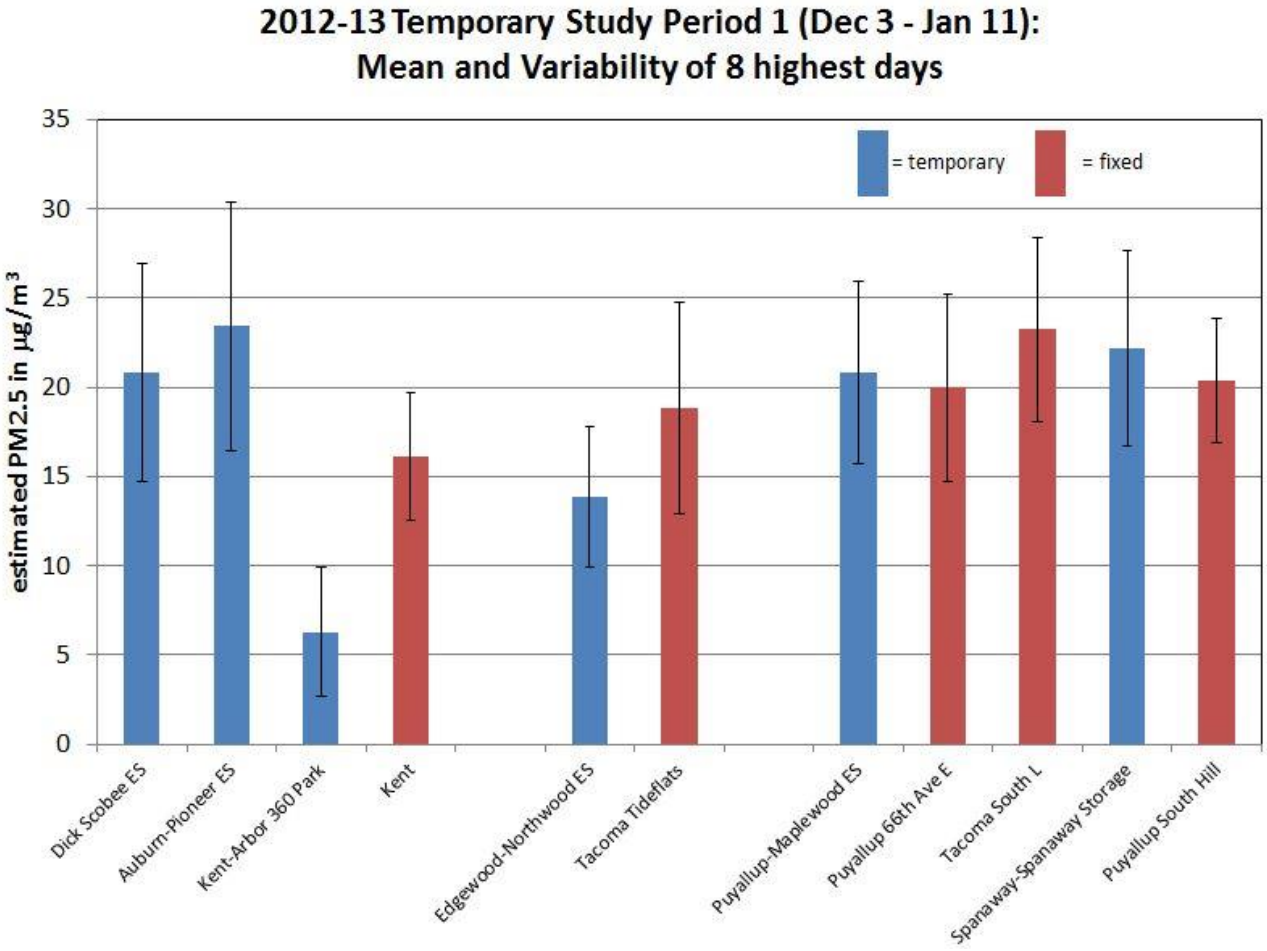

Figure 2. Period 1 Site Comparison.

Figure 3 (below) shows estimated PM 2.5 concentration Mean and Variability of the 8 highest days during the second time period analyzed. King county sites are on the left, and Pierce county sites are on the right.

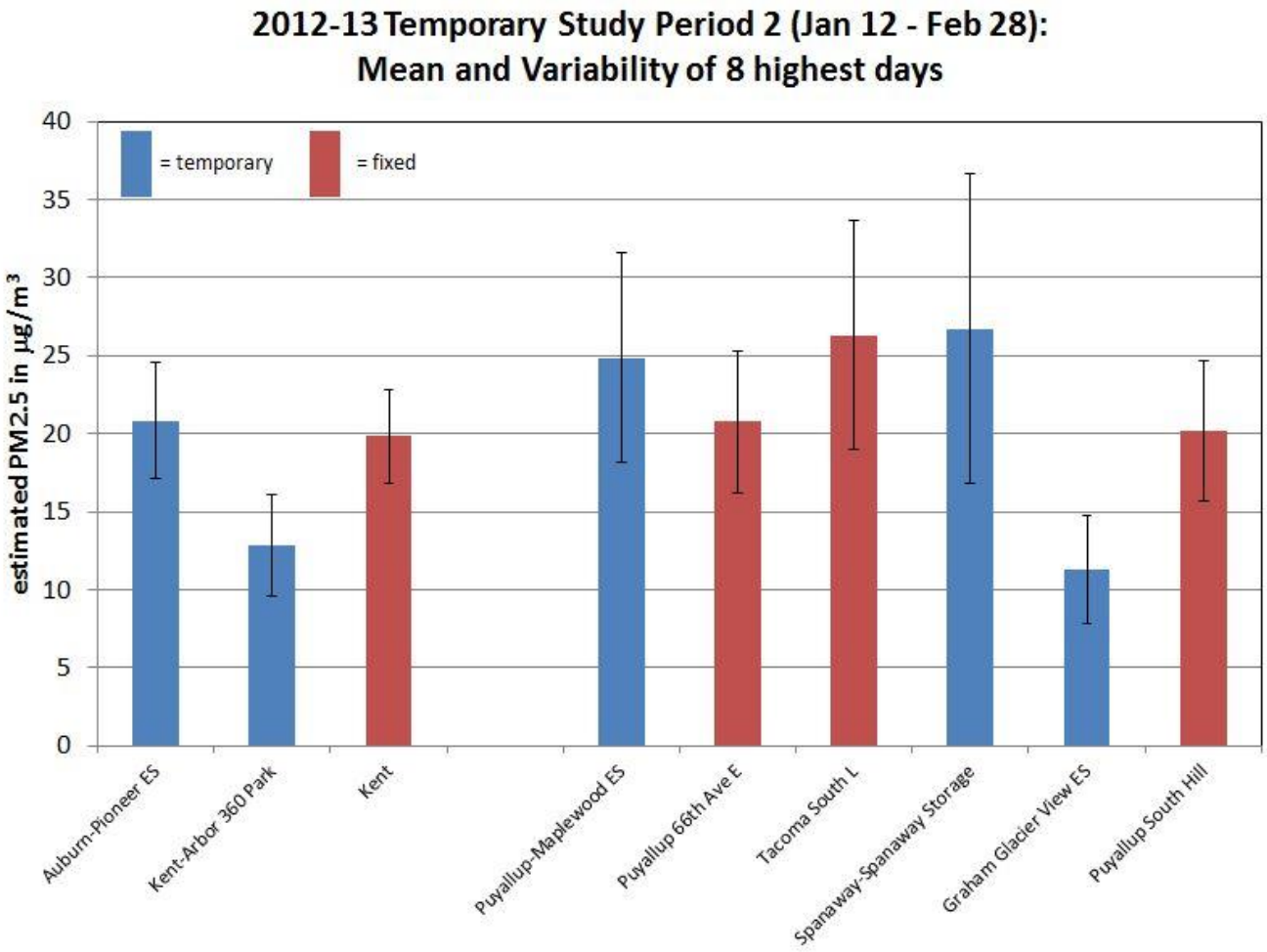

Figure 3. Period 2 Site Comparison.

The Agency conducted data analysis using summary statistics, regressions, difference analyses, and quality assurance precision estimates. While significant error exists in the results, based on all of the data analyzed, several observations were made.

1. Light scattering readings at the Auburn temporary sites more closely correlated with the Kent monitoring site. The light scattering levels, however, were higher than Kent, and were closer to Tacoma South L levels during the first half of the study.

2. Temporary sites that were located at a higher elevation than the closest fixed site (Kent – Arbor 360 Park, Edgewood, and Graham) showed generally lower levels. This confirms our understanding of how topography affects fine particle concentrations.

3. Temporary sites in Spanaway, and Puyallup very closely correlated with other Pierce county monitoring sites.

4. The highest levels of fine particle pollution occurred at Tacoma South L, Spanaway, Auburn Pioneer, and Puyallup Maplewood stations. The temporary samplers did not show any unknown hot spots. These locations have common demographic and topographic features, such as high home density, presence of wood burners, lower elevation, and the presence of economically challenged communities.

5. Although we had a limited data set, the Gig Harbor site showed lower levels compared to other Pierce county sites. The Gig Harbor site was most closely associated with the Tacoma Alexander (Tideflats) monitor, but that association was only moderate.

6. The Bonney Lake site had shelter heater problems and was erroneously sited with regard to scale, and did not provide enough valid data to make any conclusions. More sampling would be needed to characterize Bonney Lake.

Additional discussion and data is presented in the technical report. We encourage you to bring your questions to the Agency by contacting the Project Manager, Matt Harper at matth@pscleanair.org or (206) 689-4009.

END OF EXECUTIVE SUMMARY

Introduction

Fine particulate pollution (PM 2.5) is a complex mixture of extremely small particles and liquid droplets that are 2.5 micrometers in diameter and smaller[3]. PM 2.5 degrades air quality and visibility, and is linked to health effects such as premature death, heart attacks, aggravated asthma, and decreased respiratory function[4]. Many people are exposed to fine particles that are not directly measured. EPA, State, and Local ambient air quality monitoring networks have resources to cover some areas, but not all of the areas in King & Pierce County. From fixed monitors, we know that the highest levels of PM 2.5 occur during the months of November through February. The Puget Sound Clean Air Agency used temporary samplers to characterize air quality patterns in King & Pierce County from November 2012 to February 2013.

Sources of PM 2.5 include smoke from wood combustion, vehicle emissions, industrial emissions, and even natural sources. A 2009 study of Tacoma PM 2.5 speciation data reported that during the highest pollution days, wood smoke is the highest contributor[5]. Figure 4 below shows key results of the 2009 study.

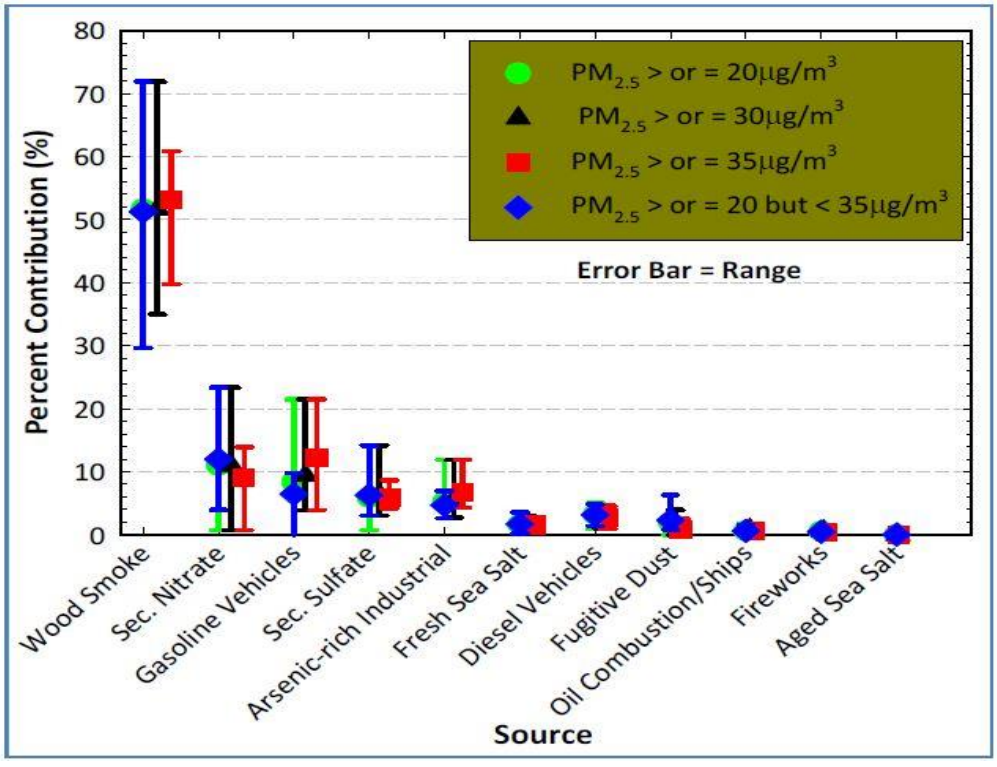

Figure 4. % contributions on days when the measured PM 2.5 concentration was elevated

[3] http://www.epa.gov/pm/
[4] http://www.epa.gov/pm/health.html
[5] Ogulei, David, "Sources of Fine Particles in the Wapato Hills-Puyallup River Valley PM 2.5 Nonattainment Area", Apr 2010 found at https://fortress.wa.gov/ecy/publications/SummaryPages/1002009.html

During other recent heating seasons, The Agency conducted similar temporary monitoring studies in Tacoma, Marysville, and Kitsap County. Results were published separately. During this season, we were interested to learn more about PM 2.5 concentrations in South King County and Pierce County. Results of the saturation-like study for sampling PM 2.5 for the winter heating season of 2012-2013 are presented in this technical report.

Study Design

Study Objectives

The primary study objective was to collect monitoring data in geographic locations where we have not collected data recently. We focused our data collection on areas where there was a concentrated population, and where burning has been observed in past winter heating seasons. Another objective was to assess the ability of fixed monitoring sites to be able to detect high concentrations of PM 2.5, especially when temporary site locations were detecting high concentrations. Having a more comprehensive understanding of the pollution patterns in the region allows us to improve our ability to forecast air quality. Having data from multiple locations allows us to ensure that we have the most efficient network of fixed monitors, so that we don't have to monitor everywhere.

Siting Considerations

Many other siting considerations were made. The sites were set up to be able to monitor at the neighborhood scale[6]. Comprehensive PM2.5 siting requirements can be found in Title 40 CFR 58, Appendix E. While siting monitors, we considered issues like operator's safety, accessibility during inclement weather, and available power sources. Among the many neighborhood scale requirements, and logistics requirements, the Agency conducted a specific analysis of potential sites in context with a new tool called the Community Assessment Tool (CAT). The tool is designed to identify areas of disproportionate impact in the region. The Agency designed this mapping tool and index, which highlights potential environmental justice areas of priority, concern, or focus. The goal of the Community Air Tool (CAT) is to align map indices with Agency priorities, increasing air quality understanding and mitigating disproportionate impacts in the region. The air monitoring sites involved in this study were located on the Community Assessment Tool, and graded using an indexed scale. The CAT accounts for three categories of information: basic demographic information, health statistics, and air quality impacts. The CAT breaks those categories down into 14 different attributes and scores each into quartiles. It evenly weighs all 14 attribute scores by totaling them. The higher the score (on a scale of 0 -37), the greater the burden and impact the community may be experiencing. The monitoring sites with CAT index score are shown in Table 1.

[6] http://www.epa.gov/ttn/amtic/files/ambient/pm25/092706sign.pdf

Monitoring Site	CAT Score
Kent Central & James	32
E Kent Arbor 360	28
Auburn Dick Scobee ES	33
Auburn Pioneer ES	24
Bonney Lake Lib Ridge ES	17
Graham Glacier View JHS	23
Puyallup Maplewood	23

Monitoring Site	CAT Score
Edgewood Northwood ES	21
Tacoma Alexander	23
Tacoma South L St	26
Spanaway	33
Gig Harbor	16
Puyallup South Hill	24
Puyallup 66th Tribal	27

Legend	CAT Score
Lowest	2-11
Low	12-16
Medium	17-21
High	22-27
Highest	28-37

Table 1. CAT index score for Study sites.

When siting choices were possible, the Agency decided to set up the sites in the location that had a higher score on the CAT index. The CAT overlay onto Google Earth is shown in Figure 5. Only areas in the High and Highest categories are shown.

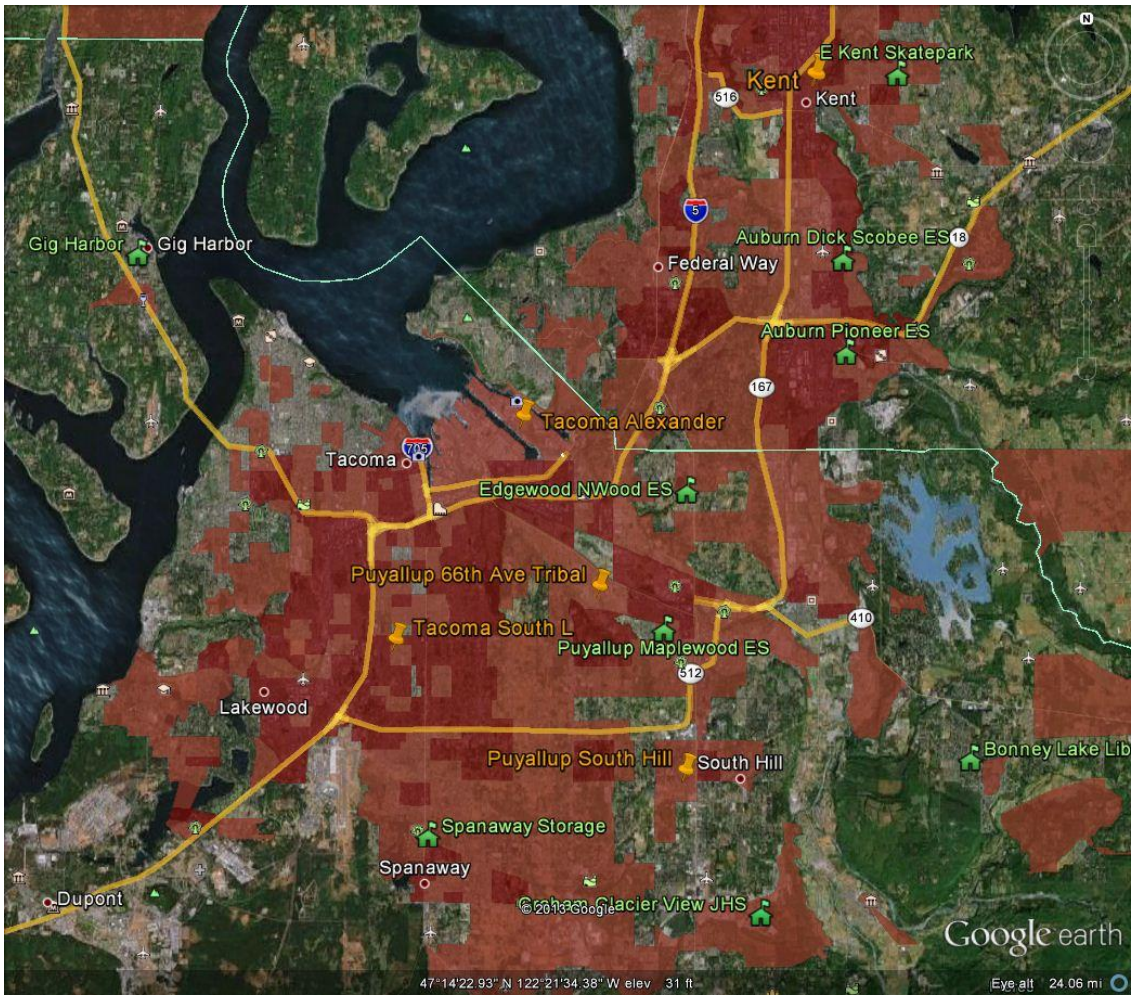

Figure 5. CAT overlay onto Google Earth.

Fixed Site Methods

Monitors at fixed sites include Ecotech and Radiance Research Nephelometers. The Washington State Department of Ecology standard operating procedure was used in each location. Additionally, many other types of monitoring were conducted at each fixed site. Fixed site methods are summarized in Table 2.

Monitoring Site	Methods	Method Purpose
Tacoma South L Street	PM 2.5 Federal Reference Method	Compliance with NAAQS
	PM 2.5 Federal Equivalent Method	Compliance with NAAQS
	PM 2.5 Nephelometer Estimation	Real Time AQI Reporting
	Aethalometer Black Carbon and UV Carbon	Wood smoke pollution differentiation
	Total Polycyclic Aromatic Hydrocarbons	Experimental method estimating total PAH contribution
	Ultrasonic Wind Sensor for WS and WD	Meteorology
Tacoma Alexander Ave	PM 2.5 Nephelometer Estimation	Real Time AQI Reporting
	Aethalometer Black Carbon and UV Carbon	Wood smoke pollution differentiation
	Ultrasonic Wind Sensor for WS and WD	Meteorology
Puyallup South Hill	PM 2.5 Nephelometer Estimation	Real Time AQI Reporting
	Aethalometer Black Carbon and UV Carbon	Wood smoke pollution differentiation
	Ultrasonic Wind Sensor for WS and WD	Meteorology
Kent Central & James	PM 2.5 Federal Equivalent Method	Compliance with NAAQS
	Aethalometer Black Carbon and UV Carbon	Wood smoke pollution differentiation
	PM 2.5 Nephelometer Estimation	Real Time AQI Reporting
	Ultrasonic Wind Sensor for WS and WD	Meteorology
Puyallup 66th Ave Tribal	PM 2.5 Nephelometer Estimation	Real Time AQI Reporting

Table 2. Fixed site methods summary.

Temporary Site Methods – For the study temporary site, we used Radiance Research Nephelometers. There were six Radiance Research nephelometers available for the study. Three sites were operational for the whole study period, and three sites were operational during the first half of the study, and then moved to the last three sites, which covered the last half of the study. A total of nine temporary monitoring sites were used to cover a wide geographic area. The Washington State Department of Ecology standard operating procedure was used[7].

Figure 6. Ecotech Nephelometer shown on left, and Radiance Research shown on right.

[7] https://fortress.wa.gov/ecy/publications/SummaryPages/0902005.html

Quality Assurance Discussion

Quality Assurance procedures were conducted at each monitor according to the WA state approved standard operating procedures. While each nephelometer was subject to accuracy and precision errors associated with variable shelter temperature, variable probe length, and variability between instruments, the operators did evaluate standard QC checks. Data from the quality control checks was collected and analyzed to estimate relative precision as shown in Table 3.

Quality Assurance Overview: Nephelometer Calibration			
	Mean Recovery (% of expected)	Recovery Relative Standard Deviation	F-Test for difference in variability
Temporary Sites	101%	5.9%	*P=0.03*
Permanent Sites	98%	4.5%	

Table 3. Nephelometer calibration check QA overview.

Temporary sites showed more relative variability during span checks, indicating that temperature control of shelters was more variable for the temporary sites. This was a challenge operationally to control due to the small footprint of the shelters and limited budget.

There are differences between Ecotech and Radiance Research nephelometers. Ecotech employs a smart heater system, which senses RH, and then heats the sample so that RH is kept below 60%. Radiance uses an older constant temperature probe heater. Further, the light sources are designed differently (Ecotech uses an array of green light emitting diodes; Radiance uses a flash lamp with green filter). These differences inherently cause variation when evaluating light scattering results for this study. Since this study was considered primarily a screening study, we were willing to accept this variation in the design. Past evaluations of Ecotech vs. Radiance nephelometers have yielded the results described in Table 4.

Ecotech v Radiance Nephelometer Regression Summary					
Site	**# of Pairs**	**Slope**	**Intercept**	**Goodness of Fit (r^2)**	**Dates**
Seattle Duwamish	307	1.00	0.01	0.99	JAN - DEC 2010
Seattle South Park	360	0.92	0.00	0.99	JAN - DEC 2012
Lynnwood	309	0.84	0.00	0.96	JAN - DEC 2010
Darrington	342	0.95	0.01	0.99	JAN - DEC 2012
Marysville	362	0.87	0.00	0.99	JAN - DEC 2012
Puyallup So Hill	341	1.02	-0.02	0.99	JAN - DEC 2011
Tacoma Alexander	342	0.82	0.01	0.99	JAN - DEC 2012
Seattle Queen Anne	363	0.92	0.00	0.97	JAN - DEC 2011
Tacoma South L St	305	0.87	0.00	0.99	JAN - DEC 2010
Tacoma South L St	337	0.94	0.01	0.99	JAN - DEC 2011

Table 4. Ecotech and Radiance nephelometer comparison summary.

Monitoring Results Analysis Methods

Regressions Analysis

Temporary monitoring site daily averages were regressed against fixed monitoring site daily averages in order to learn more about the relationships between the geographic locations. The regression results are summarized in the Table 5.

Regressions	Temporary Sites																	
Permanent	TA		TB		TC		TD		TE		TF		TG		TH		TI	
	E Kent		Aub DS		Aub Pio		Puy Map		Edgewd		Spanaw		Graham		Gig Har		Bonn Lk	
	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2	Slope	r^2
Puyallup 66th Tribal	1.28	0.5	0.92	0.92	0.87	0.89	0.89	0.92	1.29	0.87	0.63	0.81	1.58	0.87	1.25	0.64	0.54	0.64
Tacoma Alexander	1.18	0.56	0.73	0.87	0.72	0.83	0.73	0.84	1.03	0.84	0.5	0.71	1.29	0.76	1.06	0.74	0.43	0.47
Kent	1.26	0.69	0.77	0.95	0.75	0.88	0.73	0.85	1	0.88	0.52	0.77	1.39	0.81	1.12	0.63	0.46	0.56
Bremerton Spruce	0.7	0.59	0.37	0.72	0.37	0.62	0.35	0.6	0.46	0.69	0.26	0.55	0.72	0.6	0.78	0.64	0.2	0.24
Puyallup So Hill	1.25	0.52	0.84	0.87	0.84	0.89	0.85	0.91	1.22	0.85	0.59	0.79	1.51	0.89	1.21	0.51	0.51	0.67
Tacoma So L St	1.34	0.44	1.05	0.83	0.99	0.8	1.03	0.87	1.42	0.89	0.8	0.87	1.89	0.75	1.28	0.51	0.57	0.54

Table 5. Temporary and Fixed Site Regressions Summary.

Graphing Tool Results Analysis

Once relationships were established through the regression review process, we used the air graphing tool, available at http://airgraphing.pscleanair.org/ to conduct hourly and daily average analysis. An example is shown in figure 7, which shows how daily averages change throughout the data analysis periods for specific sites.

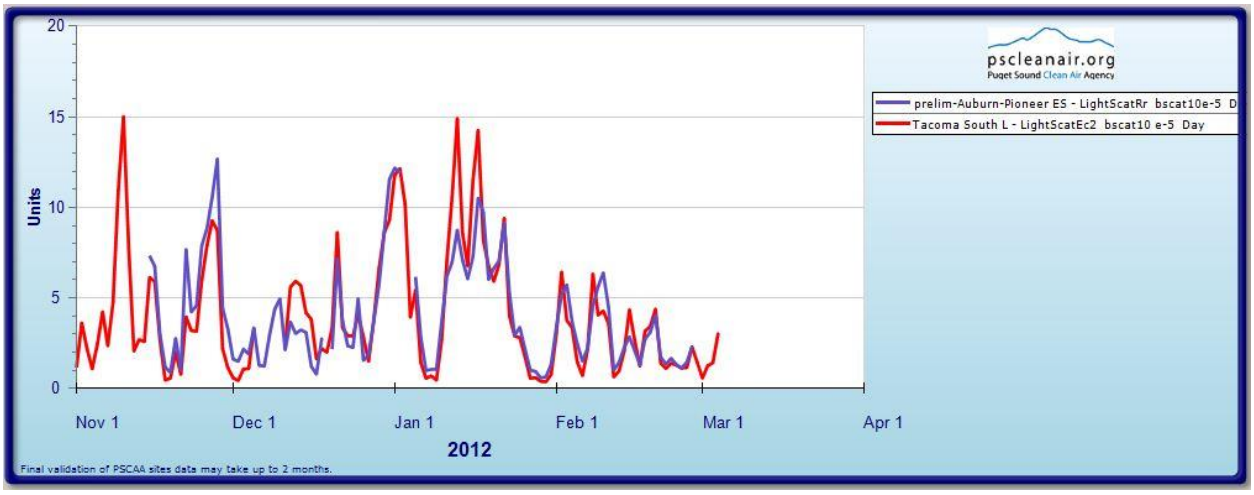

Figure 7. Graphing tool results for comparing Daily averages between Auburn Pioneer and Tacoma South L for the season.

Difference Analyses – Measuring Geographic Gap Risk

After reviewing relationships between sites, it was useful to evaluate geographic gap risk. We know that we have geographic gaps in our fixed network. We wanted evaluate the risk if we do not monitor in the geographies where the temporary monitors were sited. Specifically, we evaluated the risk of whether a temporary site could exceed our PM 2.5 health goal or the Daily NAAQS without us detecting that condition in our fixed network. In this case we may be underestimating health risk if we do not monitor at temporary site. Figure 8 describes the difference analysis tool that was used in the study.

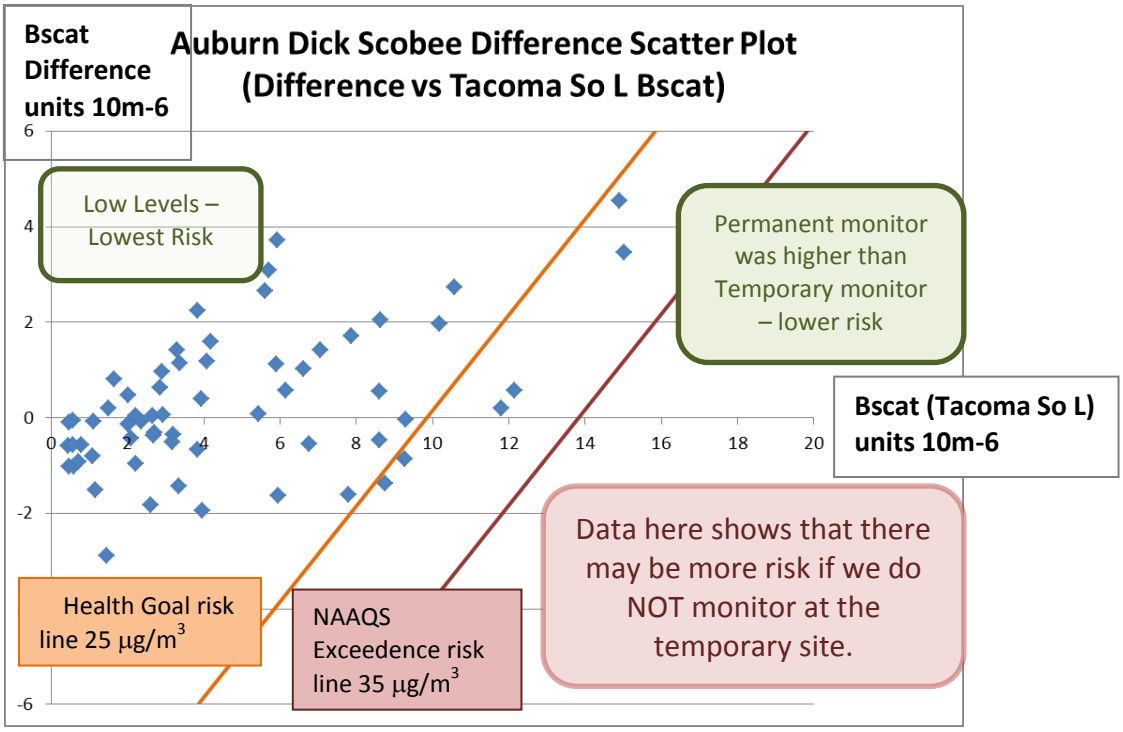

Figure 8. Example of Difference Analysis tool with Notes.

a) Daily data points (x,y) are (Bscat Fixed, Bscat Difference Fixed – Temporary).
b) Dots on the left of the Health Goal line are days when all sites show PM 2.5 levels lower than 25 µg/m^3. On the right of the Health Goal line, but to the left of the Non-attainment line are days that the temporary monitoring site exceeded the PSCAA health goal, but did not exceed the Non-attainment standard of 35 µg/m^3 of PM 2.5 in a day.
c) Dots to the right of both lines are days when the temporary monitoring site probably exceeded the PM 2.5 NAAQS.
d) Y Axis is described as **Bscat Difference = Bscat (Fixed) – Bscat (Temporary)**.
e) X Axis is simply the **Bscat (Fixed).**

Monitoring Sites and Results Discussion

The Agency chose monitoring sites in King & Pierce counties to screen areas where we have not monitored for fine particulate matter. Fixed sites were used so that levels found during the study period could be compared to fixed monitoring site levels. A variety of temporary sites were used so that we could test assumptions, and better understand monitoring data. Furthermore, the fixed sites were used as to gain spatial resolution. For this study, the Agency monitored at nine temporary sites, and thirteen fixed sites throughout the whole jurisdiction. Five fixed sites in Pierce & King counties were used primarily for data comparison, but in some instances, we also used some other fixed sites to gain overall perspective. The following results discuss how we analyzed data to come to some consensus observations. Not all sites were monitored for all pollutants. The fixed sites are shown in Figure 9. The temporary sites are shown in Green in Figure 10.

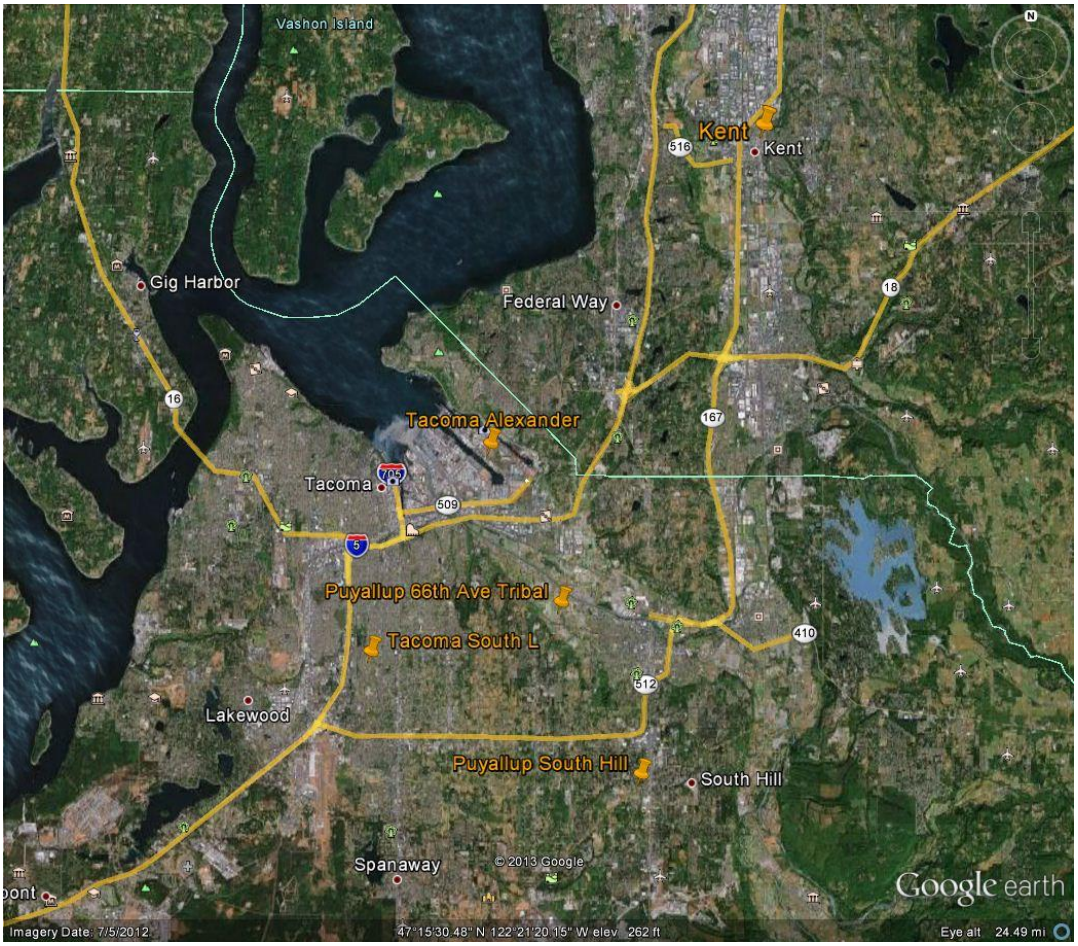

Figure 9. Fixed Monitoring Network shown in Orange pushpins.

Figure 10. Temporary sites shown in green with Fixed sites shown in orange.

In South King County, the Agency has monitored pollution at the Kent Central & James station since 1987. The Kent monitoring site is located at the corner of the busy intersection of Central Avenue & James Street. The elevation at the monitoring site is only 43 feet above Sea level, so it is situated in the Auburn-Kent-Renton valley. The site provides an excellent historical long-term picture of how PM 2.5 levels have changed since 1987.

Code	Temporary Site Location	Address	StartDate	EndDate	County	Elev (ft)	Latitude	Longitude	Scale
TA	E Kent-Arbor 360 Park	240th Street & 116th Avenue, Kent	06-Nov-12	24-Jan-13	King	481	47.3861	-122.188	Neighborhood
TB	Auburn-Dick Scobee ES	1031 14th Street NE, Auburn	09-Nov-12	16-Jan-13	King	66	47.3211	-122.216	Neighborhood
TC	Auburn-Pioneer ES	2301 M Street SE, Auburn	14-Nov-12	28-Feb-13	King	110	47.2875	-122.214	Neighborhood
TD	Puyallup-Maplewood ES	1110 W Pioneer, Puyallup	26-Nov-12	28-Feb-13	Pierce	36	47.1894	-122.310	Neighborhood
TE	Edgewood-Northwood ES	9805 24th Street E, Edgewood	16-Nov-12	11-Jan-13	Pierce	364	47.2386	-122.298	Neighborhood
TF	Spanaway-Spanaway Storage	16413 1st Avenue Ct S, Tacoma	08-Nov-12	28-Feb-13	Pierce	361	47.1167	-122.433	Neighborhood
TG	Graham Glacier View ES	12807 184th St E, graham	11-Jan-13	28-Feb-13	Pierce	531	47.0890	-122.260	Neighborhood
TH	Gig Harbor City Hall	3510 Grandview St, Gig Harbor	29-Jan-13	28-Feb-13	Pierce	309	47.3228	-122.585	Neighborhood
TI	Bonney Lake Liberty Ridge ES	12202 209th Ave Ct E, Bonney Lake	25-Jan-13	28-Feb-13	Pierce	640	47.1442	-122.152	Unknown
Code	Permanent Site Location	Address	StartDate	EndDate	County	Elev (ft)	Latitude	Longitude	Scale
EQ	Tacoma Tideflats	2301 Alexander Ave, Tacoma	02-Mar-87	N/A	Pierce	3	47.2656	-122.386	Neighborhood
ER	Puyallup South Hill	South Hill, 9616 128th St E, Puyallup	29-Dec-91	N/A	Pierce	442	47.1401	-122.300	Neighborhood
ES	Tacoma South L	7802 South L St, Tacoma	03-Oct-99	N/A	Pierce	341	47.1864	-122.452	Neighborhood
EX	Puyallup 66th Ave E	Fish Hatchery, 5722 66th Ave E, Puyallup	01-Jul-04	N/A	Pierce	32	47.2053	-122.339	Neighborhood
CW	Kent	James St and Central Ave, 614 N Railroad, Kent	27-May-87	N/A	King	42	47.3861	-122.232	Neighborhood

Table 6. Monitoring Site Locations

E Kent Arbor 360

The following regressions compared site TA (E Kent Arbor 360) to the fixed sites.

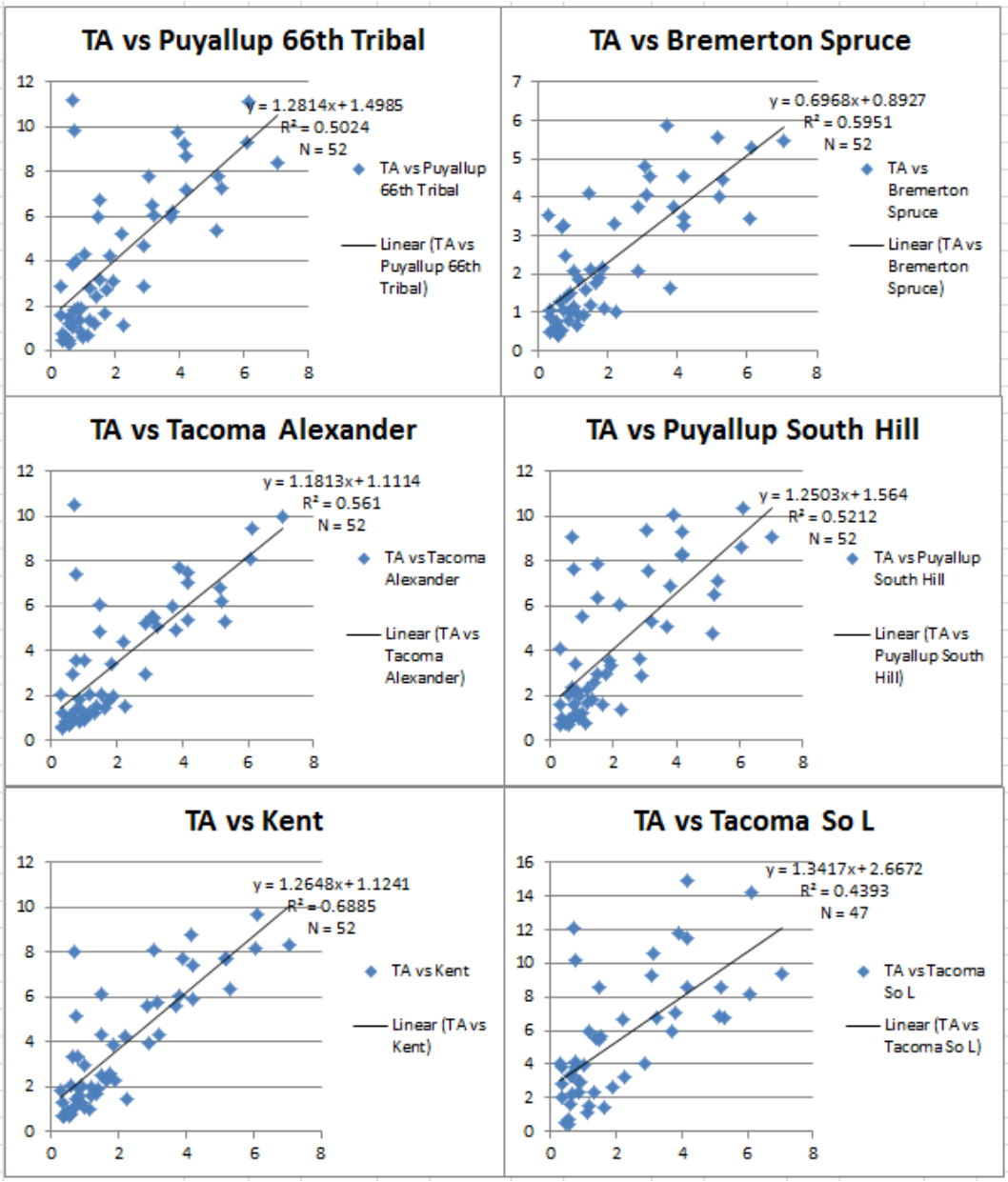

Figure 11. E Kent Regressions.

E Kent most closely resembled the Kent monitoring site (R^2 = .69), but was notably lower on almost every day (slope = 1.26). The E Kent site was located at 481 ft. above sea level, whereas the Kent fixed monitoring site is at 43 ft. above sea level. In this case, the site which showed the higher pollution levels was the site with the lower elevation.

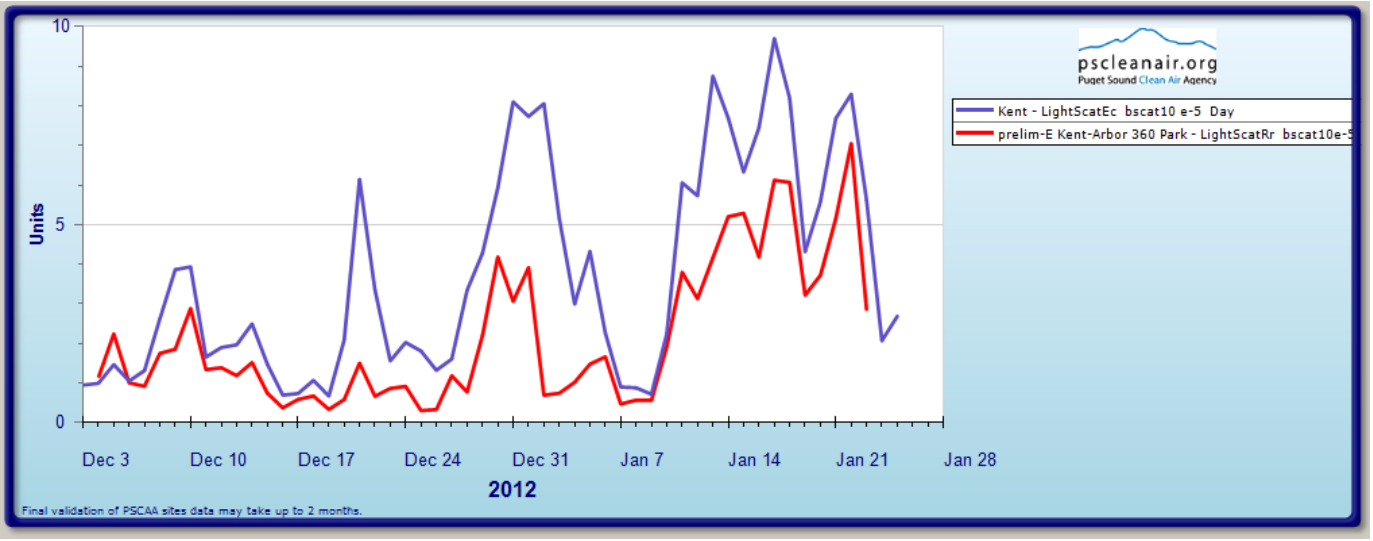

Figure 12. E Kent Arbor 360 Park v Kent light scattering series.

Figure 12 above shows that light scattering values measured at the Arbor 360 park temporary site were significantly lower than the values measured at the Kent fixed site. Difference Analysis as shown in Figure 13 was conducted for the E Kent site, which confirmed that there is low risk associated with exceeding the Agency's PM 2.5 health goal.

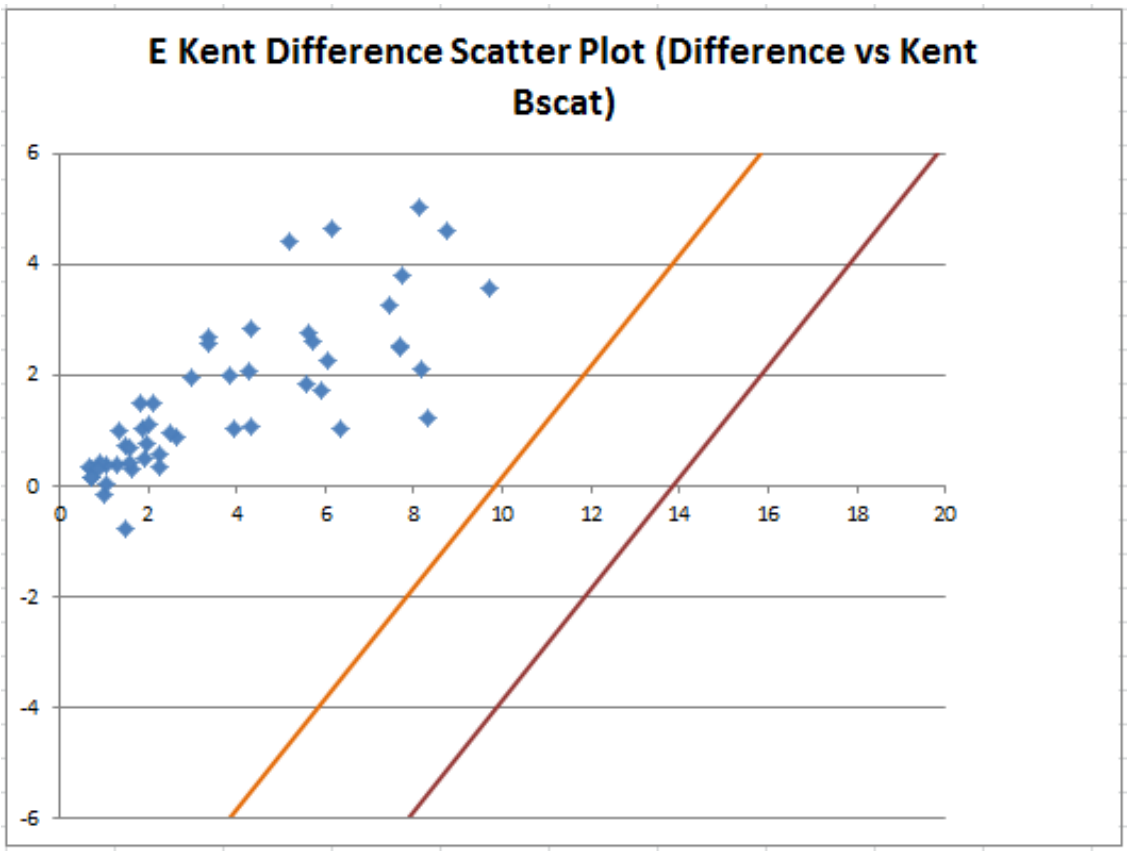

Figure 13. E Kent v Kent Difference Analysis.

Auburn Dick Scobee Elementary School

The following regressions compared site TB (Auburn Dick Scobee) to the fixed sites.

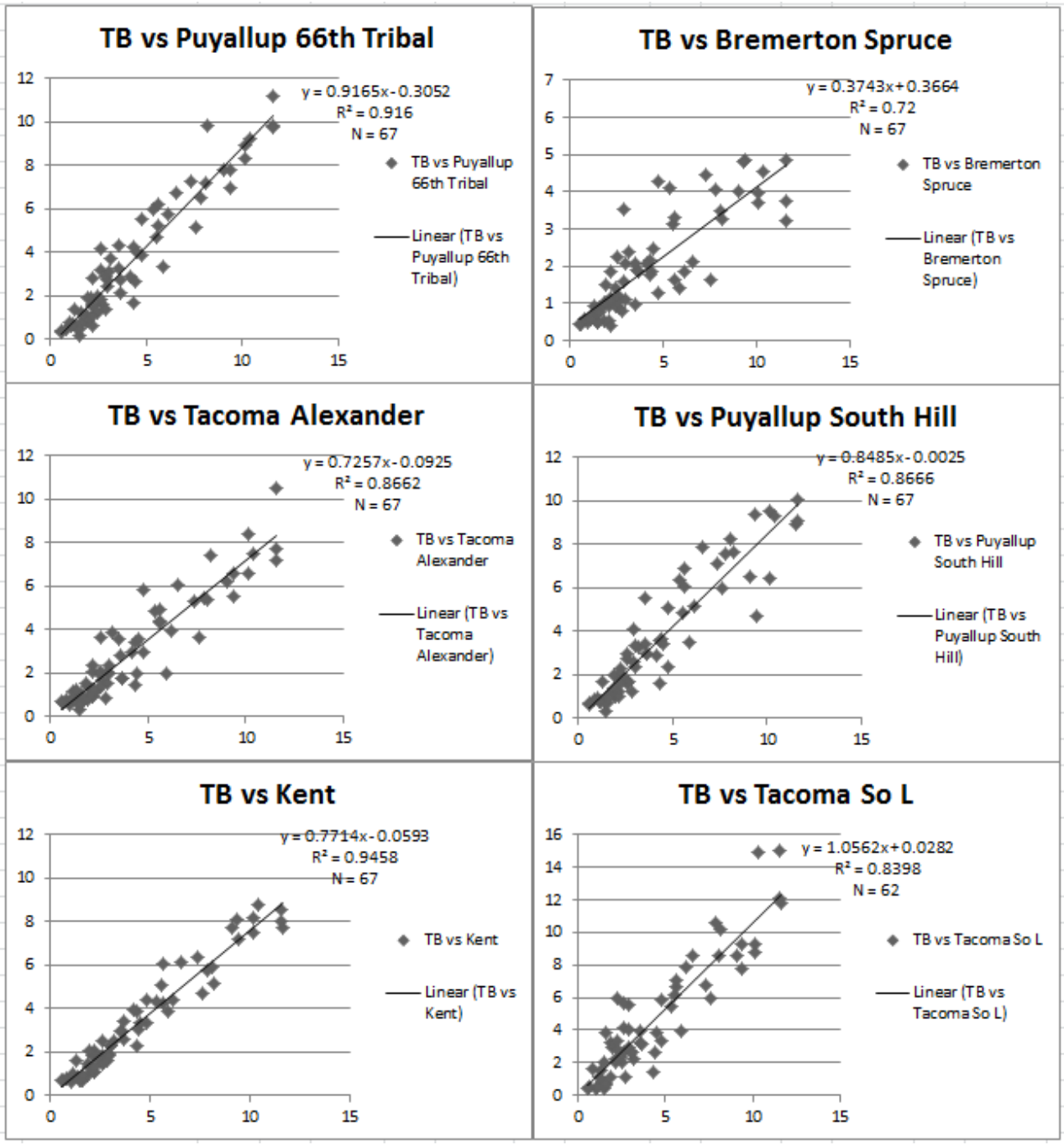

Figure 14. Auburn Dick Scobee regressions.

Auburn Dick Scobee most closely resembled the Kent site (R^2 = .95). Both sites are fairly close geographically, and both sites were placed in the same valley topographic feature. Auburn Dick Scobee was usually higher than Kent (slope = .77), but lower than Tacoma So L (slope = 1.05)

and as shown in Figure 15. During the highest days, the Auburn Dick Scobee data showed levels very close to Tacoma South L data.

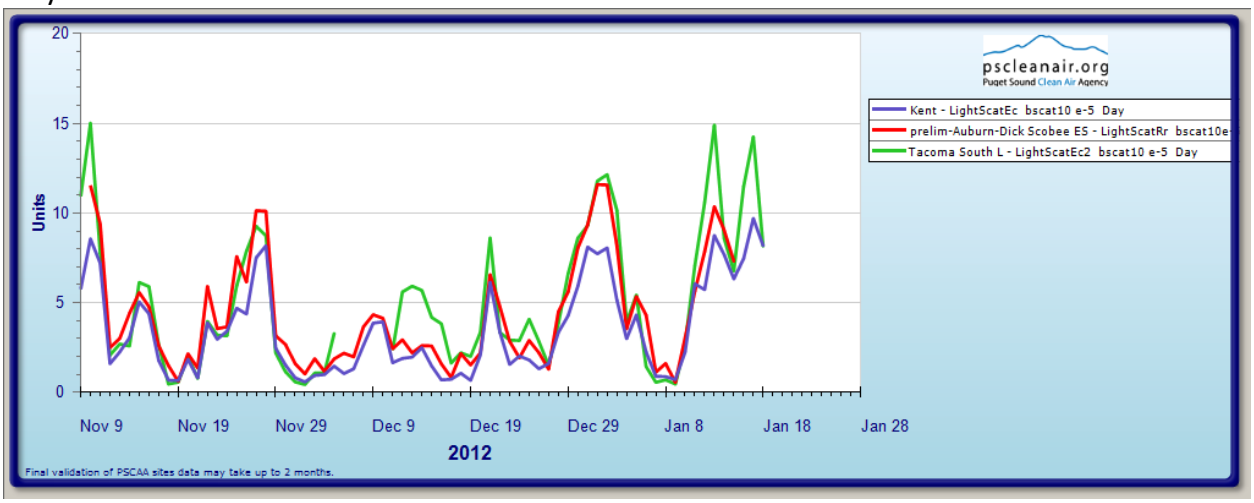

Figure 15. Auburn Dick Scobee v Kent & Tacoma South L light scattering series.

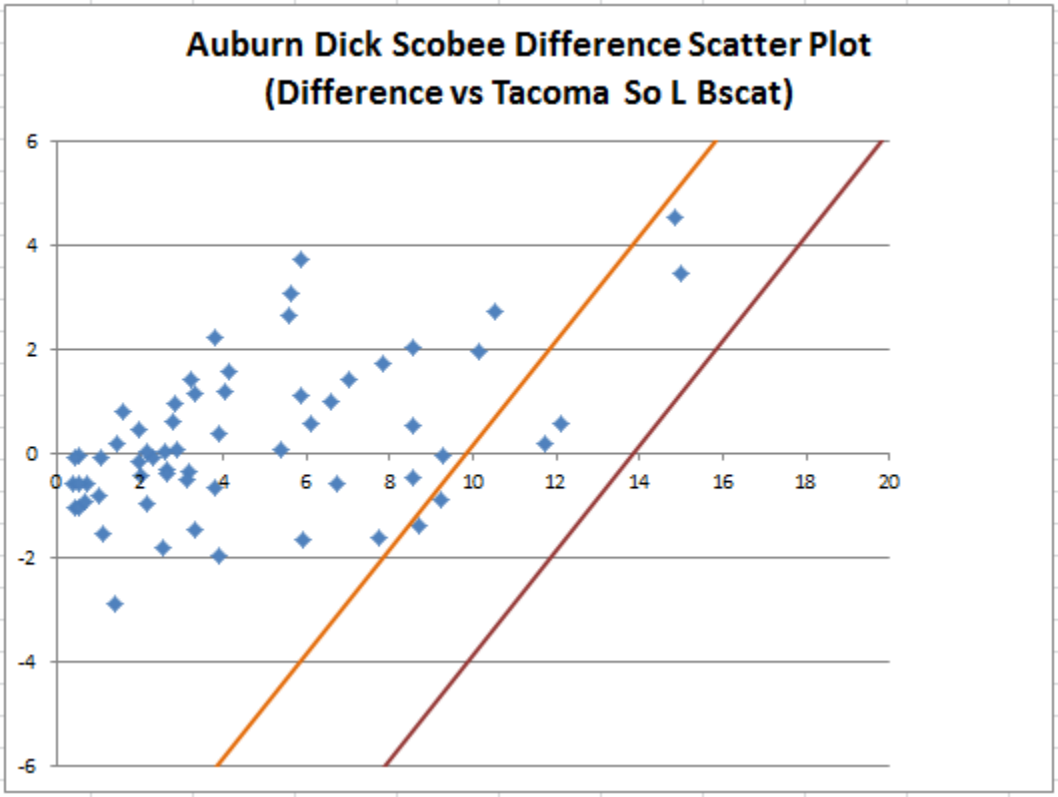

Figure 16. Auburn Dick Scobee v Tacoma So L Difference Analysis

Figure 16 shows that if pollution levels in North Auburn exceeded the Agency's health goal, then the Tacoma So L monitor would also show levels that would exceed the Agency health goal.

Auburn Pioneer Elementary School

The following regressions compared site TC (Auburn Pioneer) to the fixed sites.

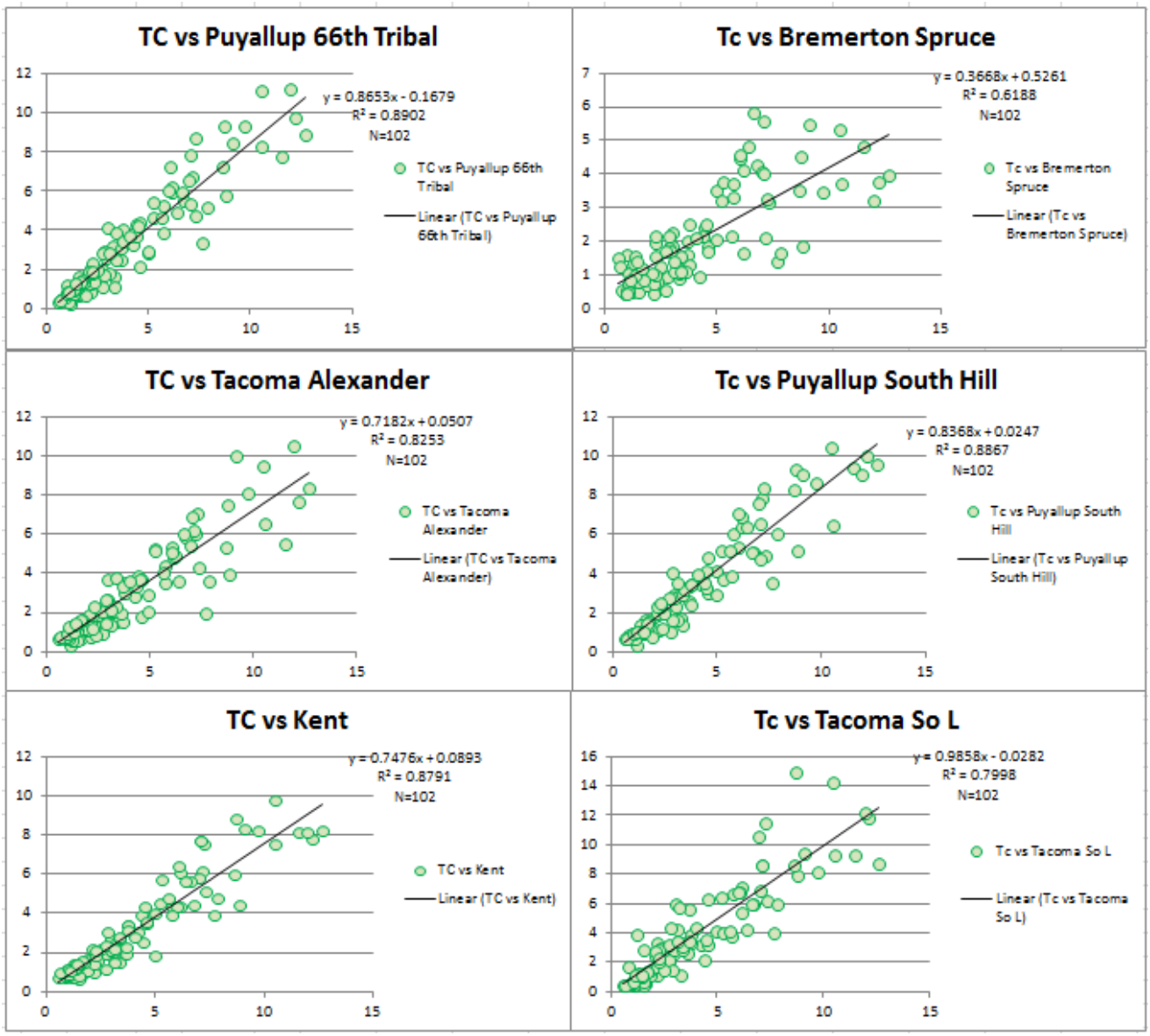

Figure 17. Auburn Pioneer regressions.

Auburn Pioneer closely resembled Kent, Puyallup Tribal, and Puyallup South Hill sites (R^2 = .88, .89, and .89 respectively). The Auburn and Kent sites are in King county, whereas the Puyallup sites are in Pierce county. Both Auburn sites (Dick Scobee and Pioneer) also acted similarly in similar meteorological conditions. There were days when nephelometer data indicated that Auburn Pioneer may have had higher daily PM 2.5 values than Tacoma South L.

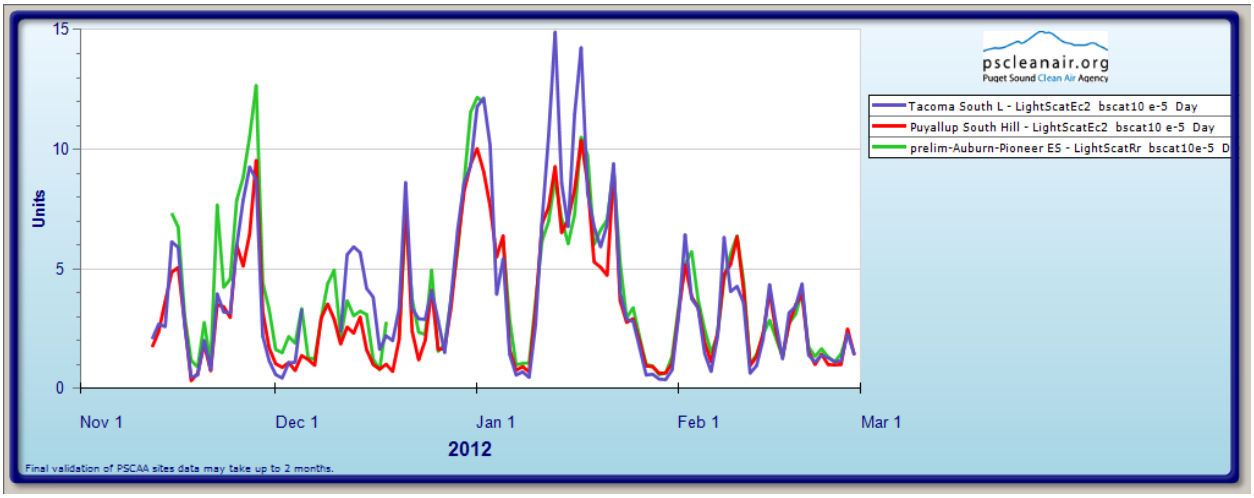

Figure 18. Auburn Pioneer v Puyallup So Hill & Tacoma South L light scattering series.

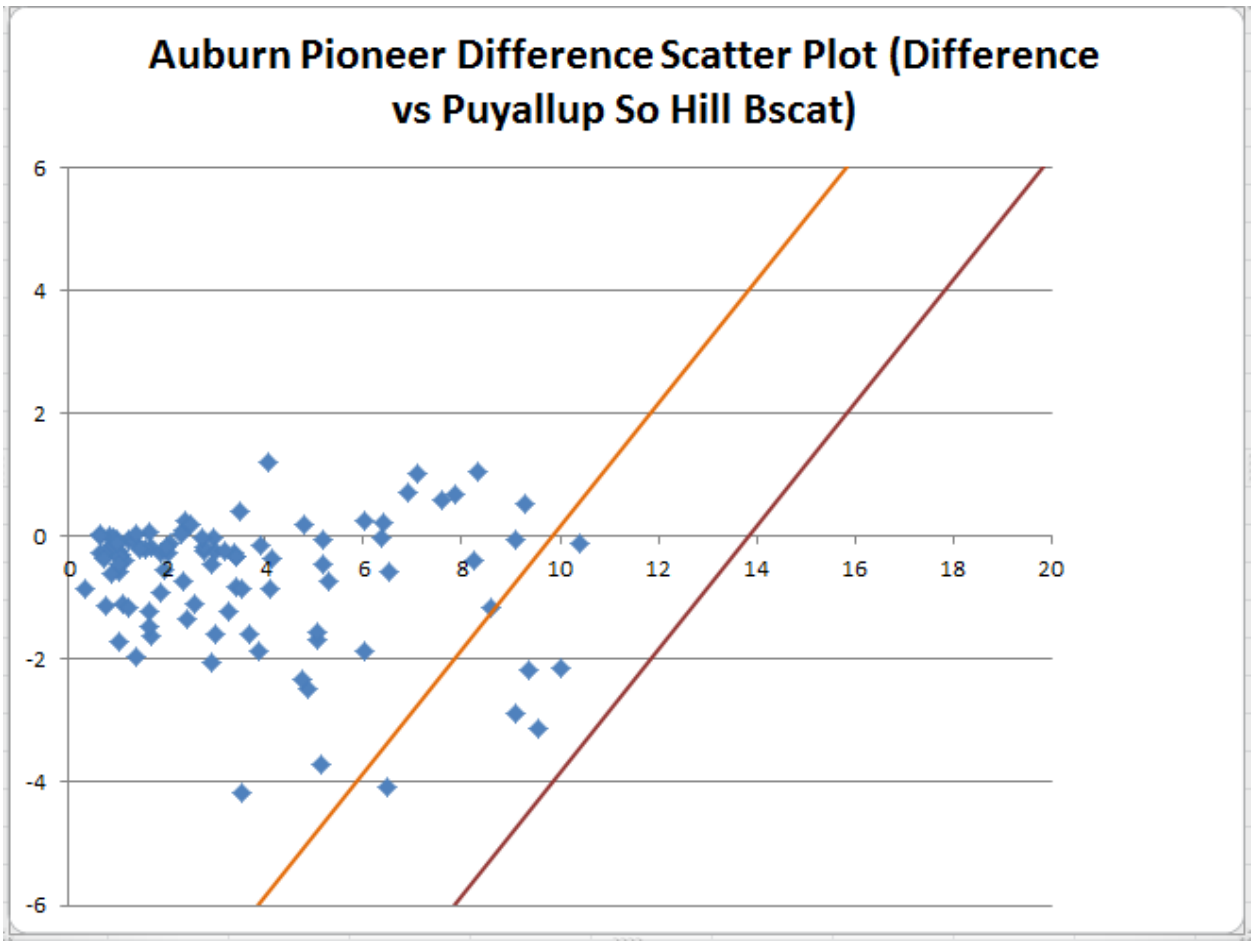

Figure 19. Auburn Pioneer v Puyallup So Hill Difference Analysis

Puyallup Maplewood Elementary School

The following regressions compared site TD (Puyallup Maplewood) to the fixed sites.

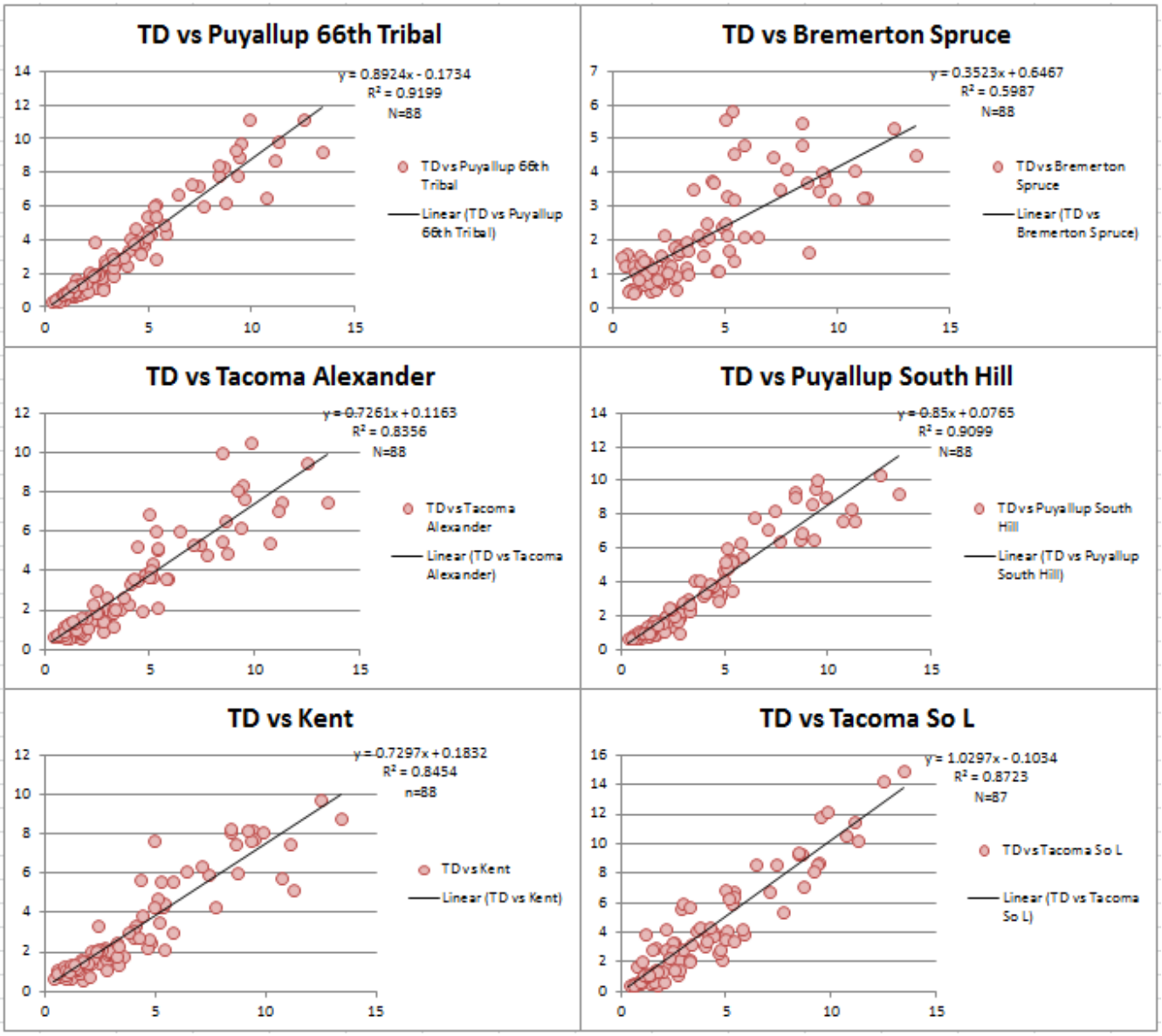

Figure 20. Puyallup Maplewood regressions.

The Puyallup Maplewood site very closely resembles the Puyallup 66th Tribal site (R^2 = .92), and the Puyallup South Hill monitoring site (R^2 = .91). The Maplewood Elementary school site is closer to the homes burning wood, and also shows higher values normally than Tribal or South Hill sites (slope = .89 and .85 respectively). It appears that monitoring sites in the valley area act similarly during high pollution episodes. Tacoma South L appears slightly higher than Puyallup Maplewood (slope = 1.03) as shown in Figure 21.

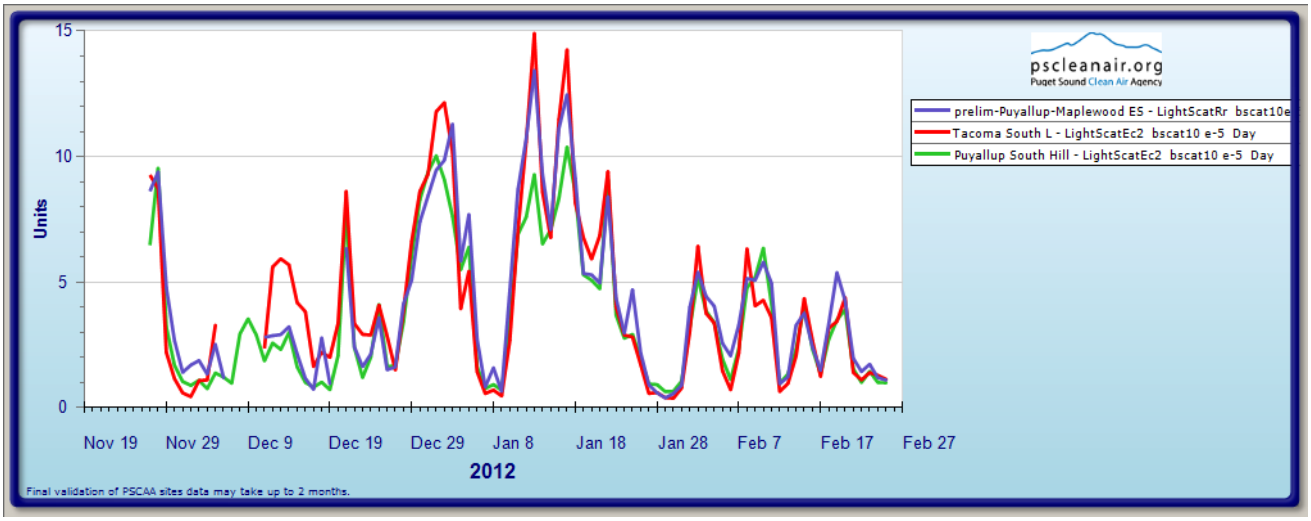

Figure 21. Puyallup Maplewood v Puyallup So Hill & Tacoma South L light scattering series.

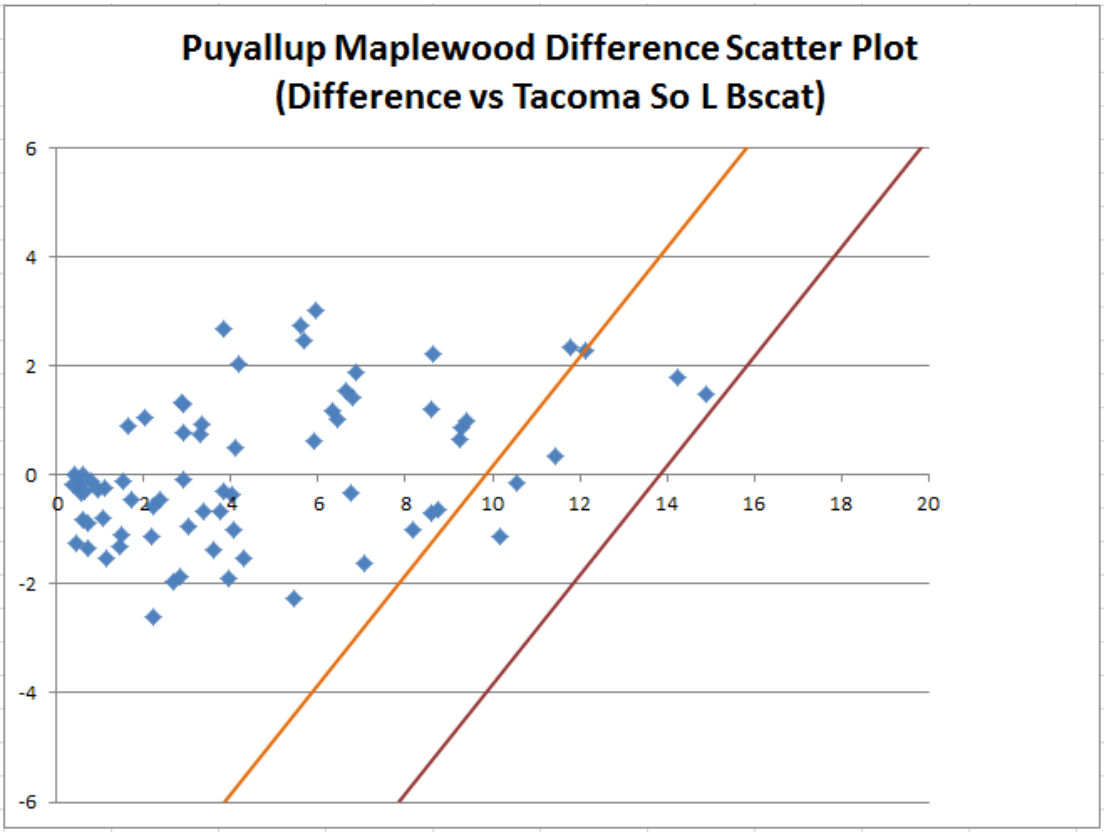

Figure 22. Puyallup Maplewood v Tacoma South L Difference Analysis.

Figure 22 shows that if pollution levels in Puyallup exceeded the health goal, then the Tacoma South L monitor would likely show a health goal exceedence.

Edgewood Northwood Elementary School

The following regressions compared site TE (Edgewood Northwood ES) to the fixed sites.

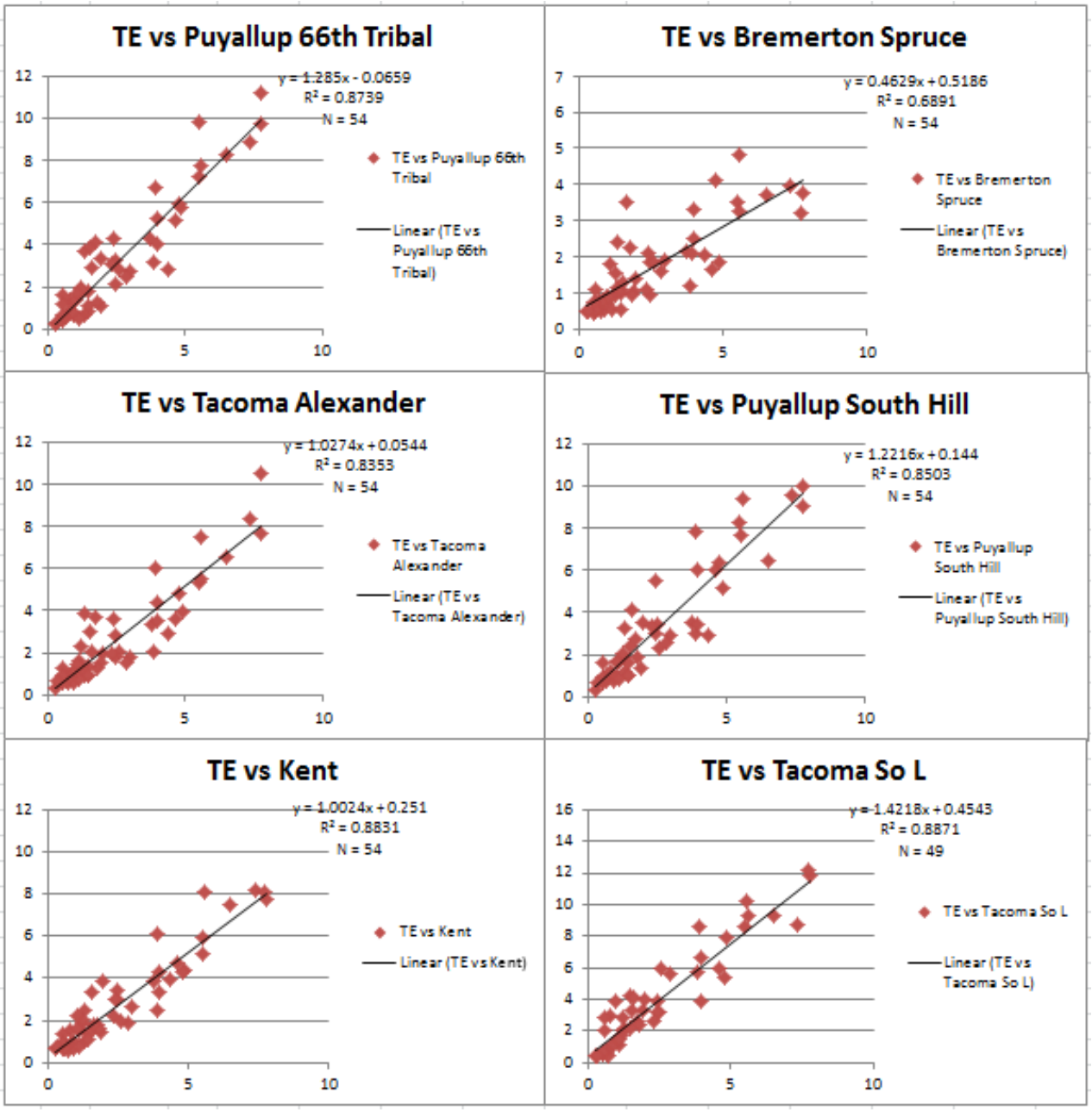

Figure 23. Edgewood regressions.

The Edgewood site most closely correlated with Tacoma South L , Kent, and Puyallup Tribal (R^2 = .89, .88, and .87 respectively). Edgewood had lower PM 2.5 concentrations than Tacoma South L (slope = 1.42), and Puyallup (slope = 1.29), but was very close to Kent (slope = 1.00). The Edgewood monitoring site had lower density housing than comparable sites, and was located at a higher elevation (367 ft. above sea level) than comparable sites, so this result is not surprising.

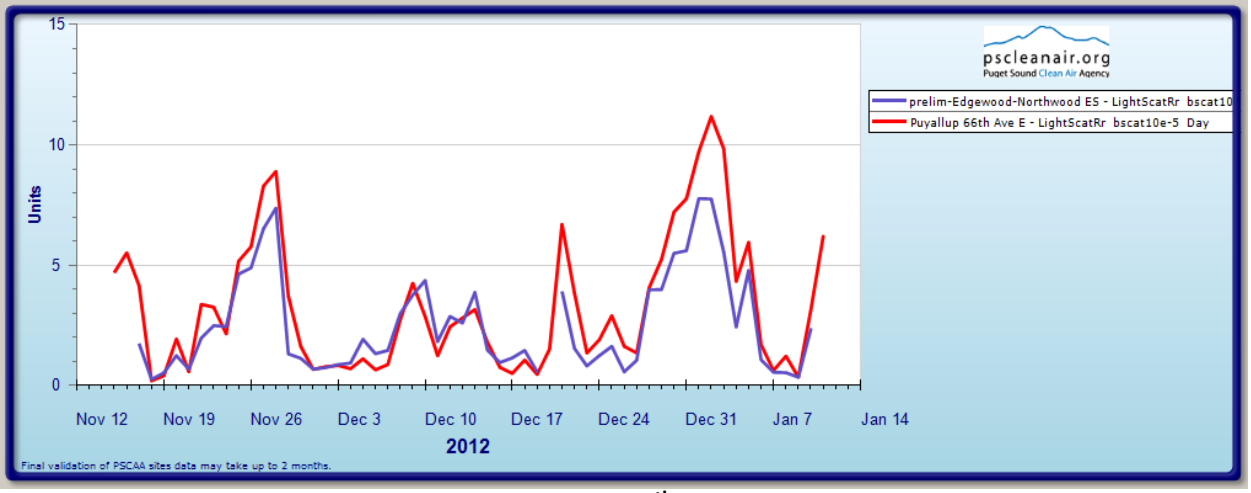

Figure 24. Edgewood v Puyallup 66th Tribal light scattering series.

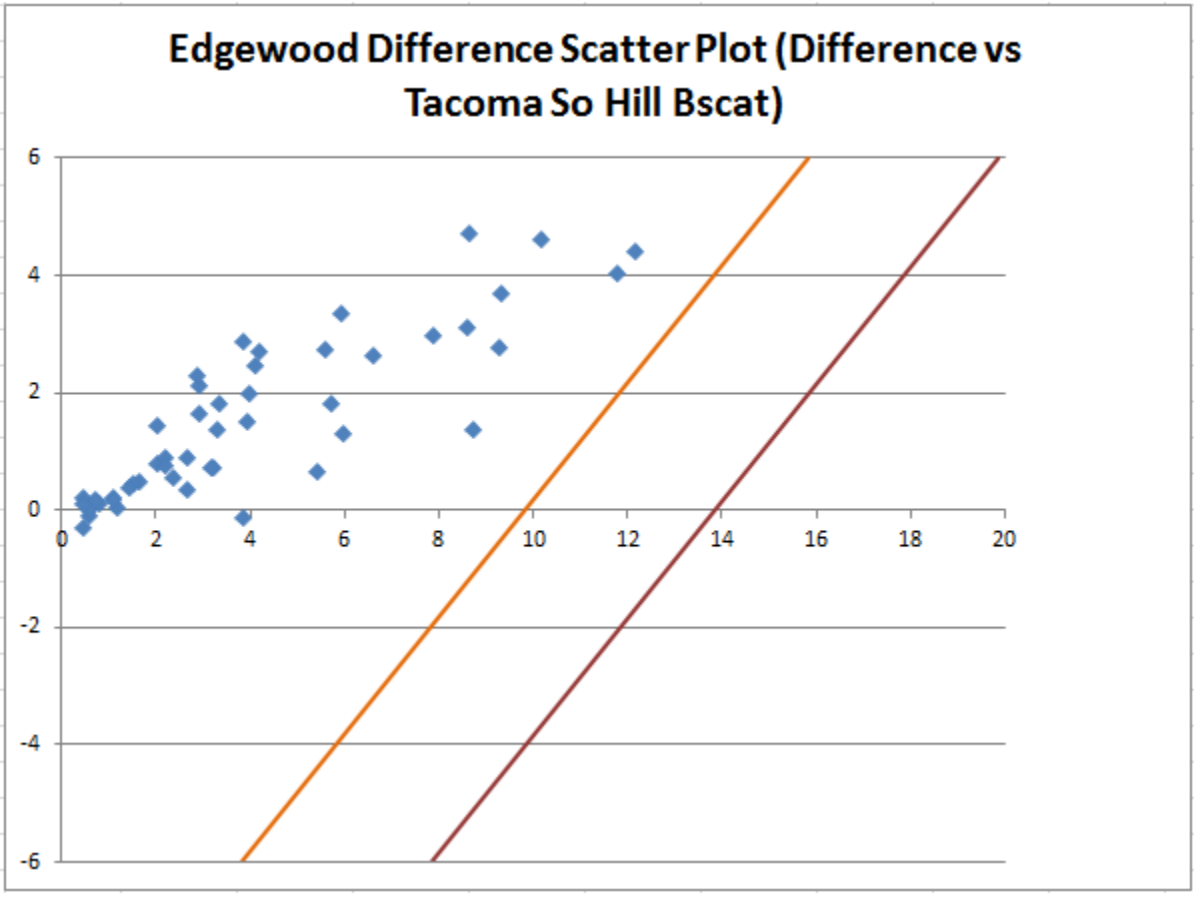

Figure 25. Edgewood v Tacoma So L Difference Analysis.

Figure 25 shows that Edgewood light scattering values were low, and do not risk an exceedence of the health goal or the NAAQS.

Spanaway A Storage Center

The following regressions compared site TF (Spanaway) to the fixed sites.

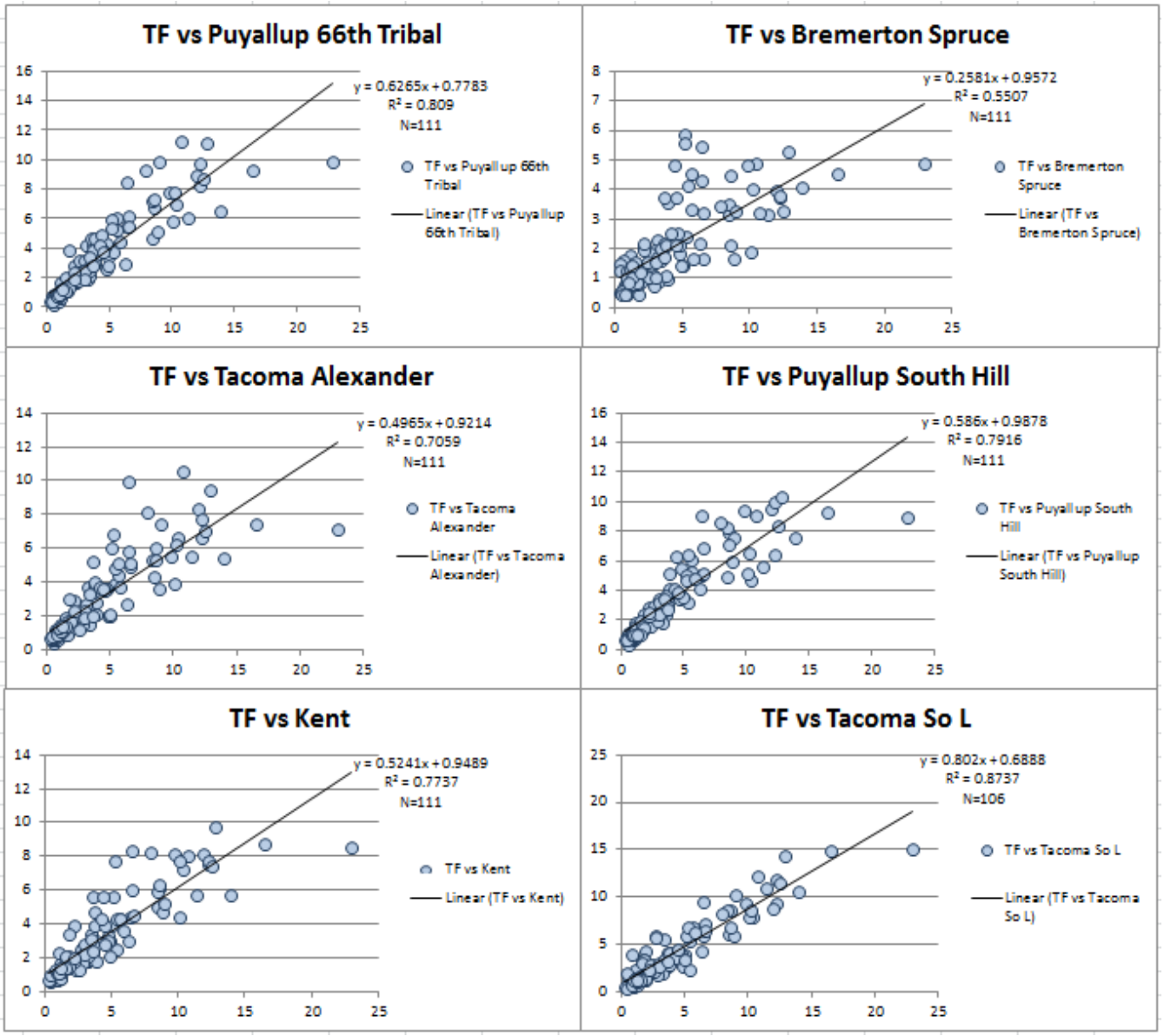

Figure 26. Spanaway regressions.

Spanaway most closely correlated with Tacoma South L (R^2 = .87), and yielded higher results than Tacoma South L (slope = .80) as shown in Figure 27.

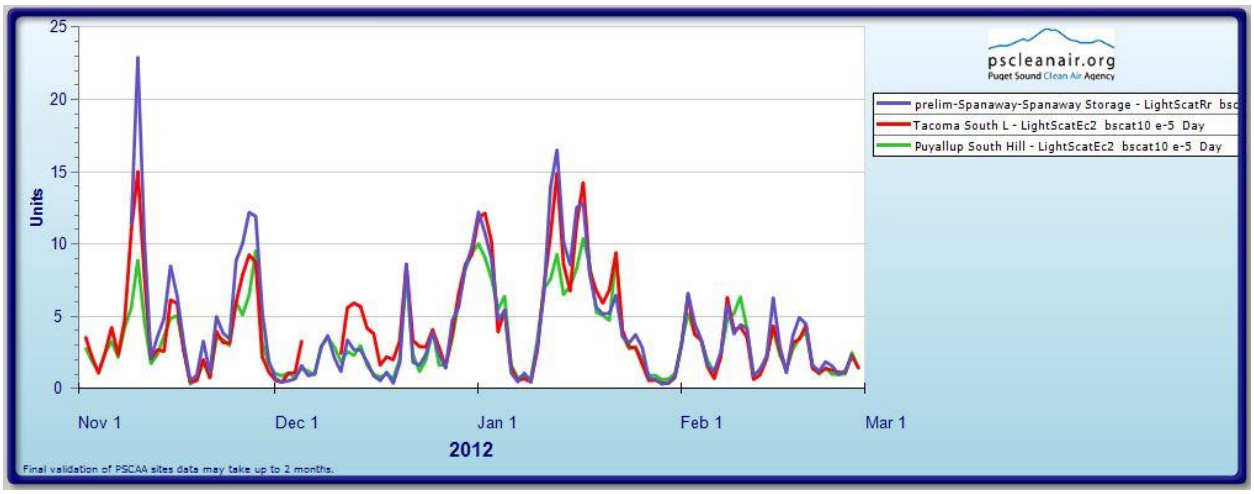

Figure 27. Spanaway v Tacoma So L & Puyallup So Hill light scattering series.

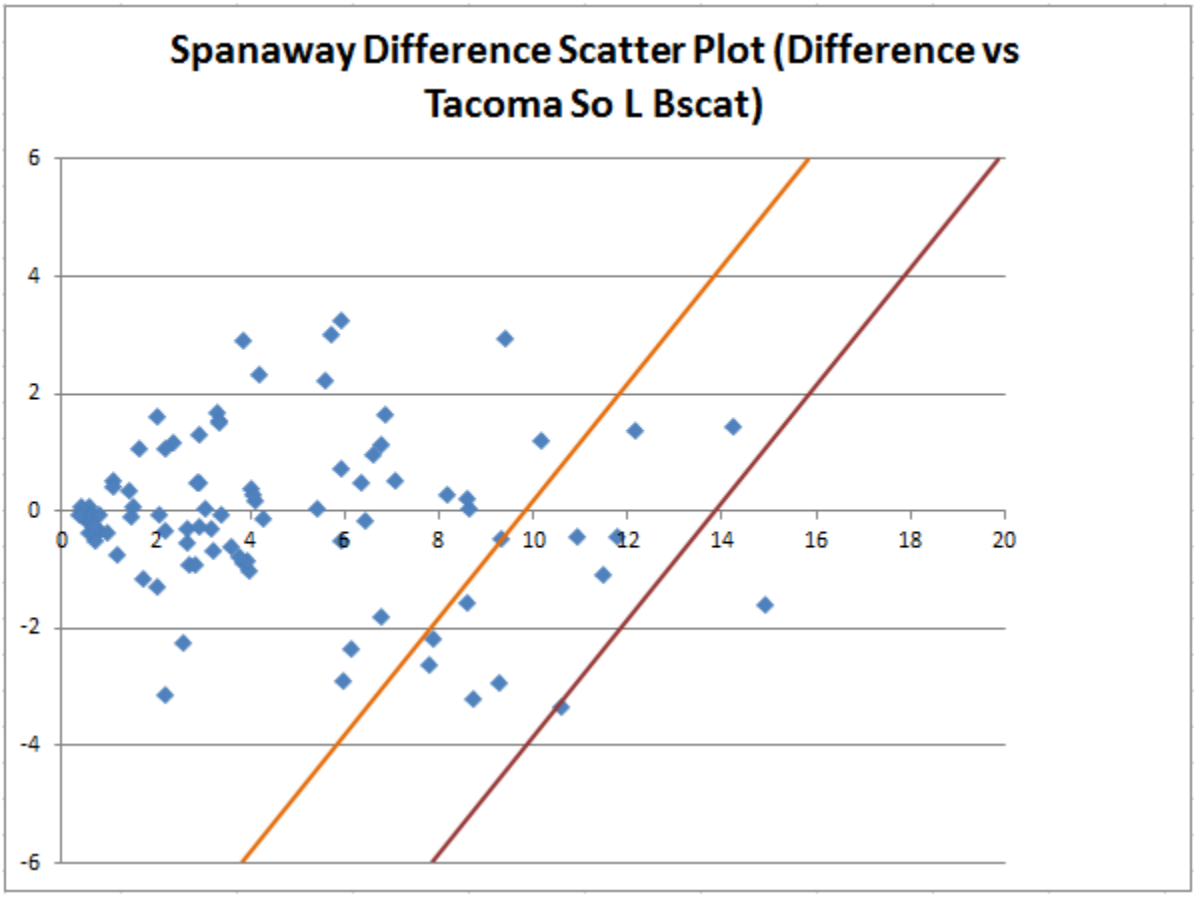

Figure 28. Spanaway v Tacoma So L Difference Analysis.

Graham Glacier View JHS

The following regressions compared site TG (Graham) to the fixed sites.

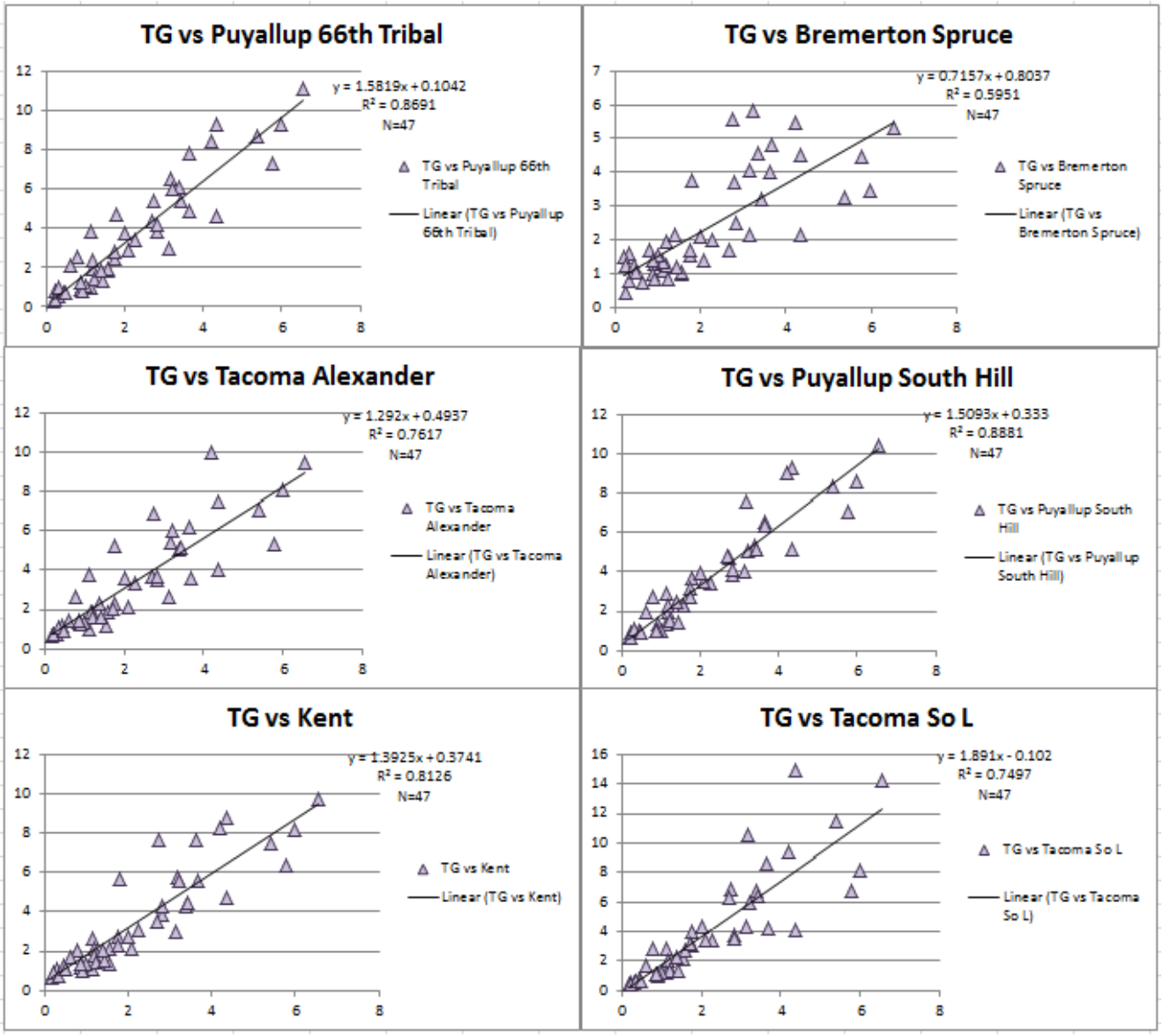

Figure 29. Graham regressions.

Graham most closely resembled Puyallup South Hill (R^2 = .89), and had generally lower pollution values than the fixed monitors in Pierce County as shown in Figure 30. Graham's monitoring site was higher in elevation (534 ft. above sea level) than the Puyallup and Tacoma monitors. The housing density near the Graham monitor was light. The monitoring site was neighborhood scale. Figure 31 shows that Graham is not at risk of exceeding the Agency's PM 2.5 health goal.

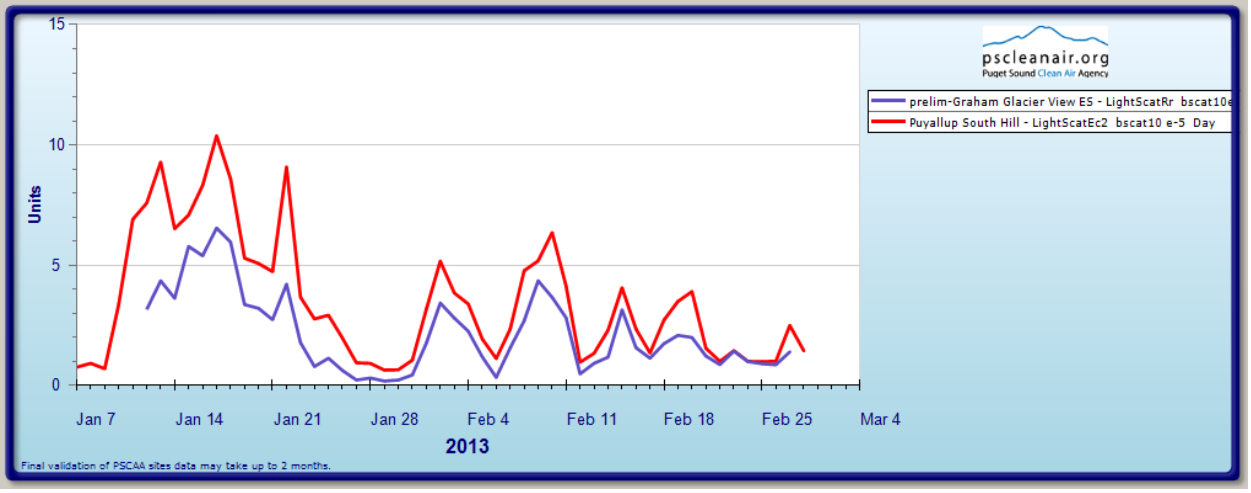

Figure 30. Graham v Puyallup So Hill light scattering series.

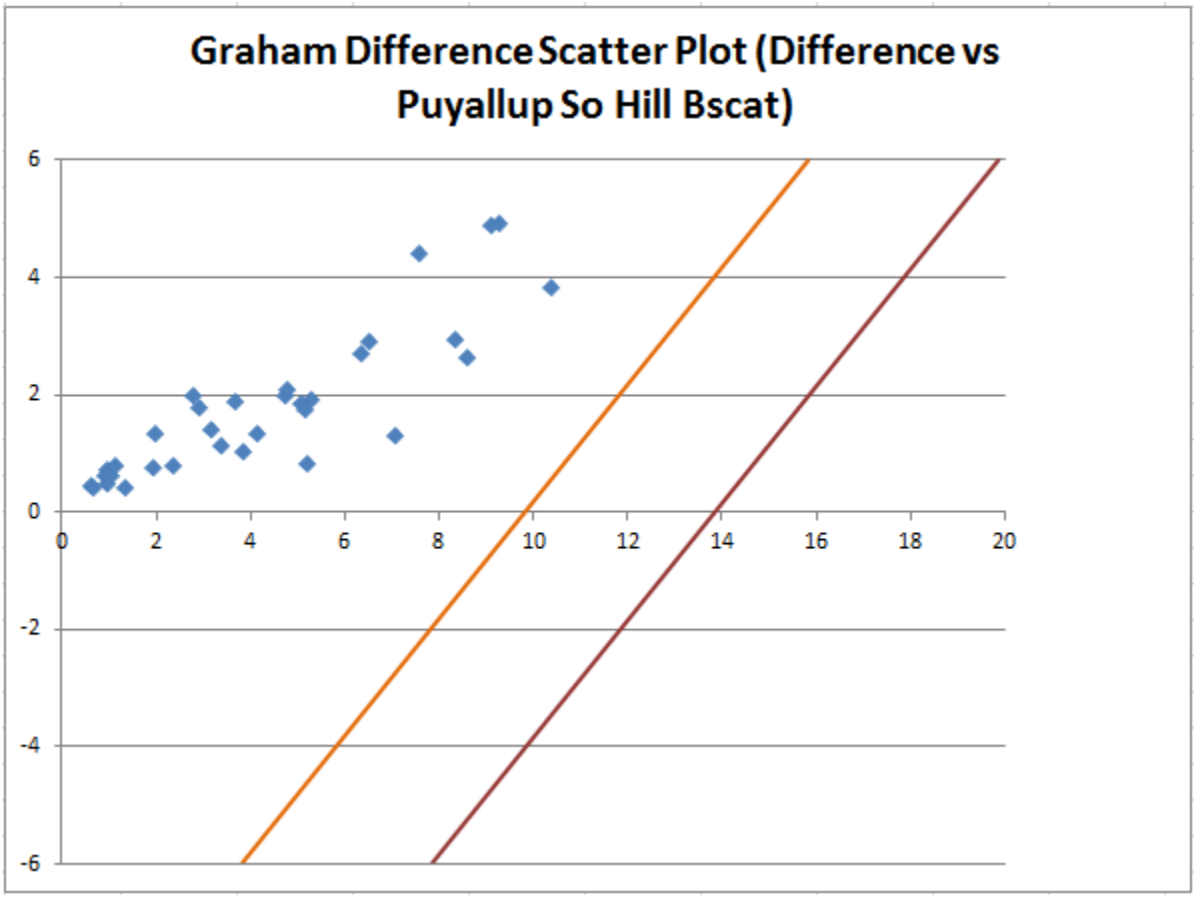

Figure 31. Graham v Puyallup So Hill Difference Analysis.

Gig Harbor City Hall

The following regressions compared site TH (Gig Harbor) to the fixed sites.

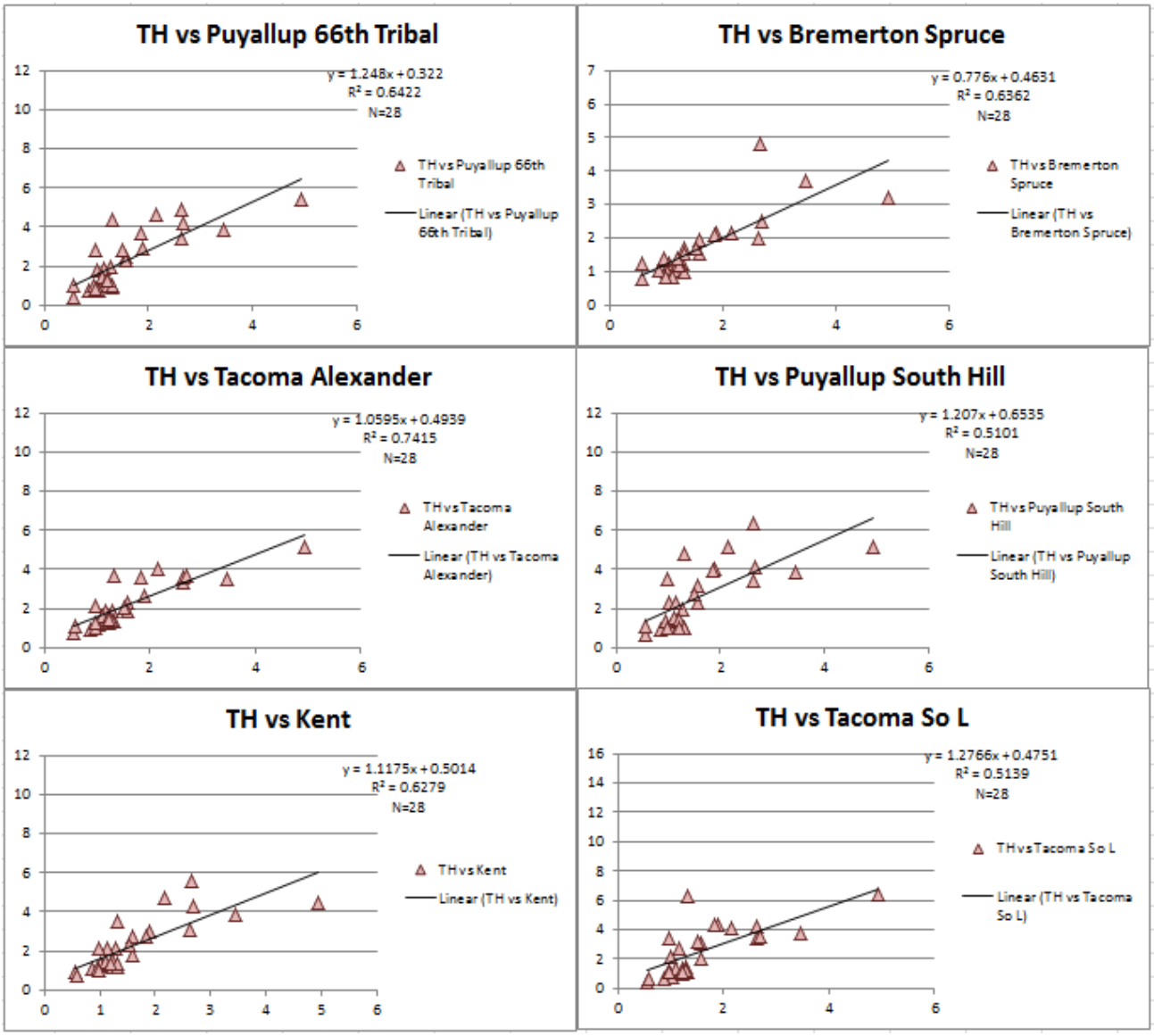

Figure 32. Gig Harbor regressions.

The Gig Harbor data set is very limited, with only 28 data points observed and none at elevated levels. Gig Harbor data most closely correlated with the Tacoma Alexander monitoring site (R^2 = .74, slope = 1.06). Although not the strongest relationship, inherently, it is not surprising that Gig Harbor resembled the nearest monitoring site. However with so few data points, and with the meteorologically complex Tacoma Narrows situated in between the Tideflats and the Gig Harbor area, no conclusions can be drawn.

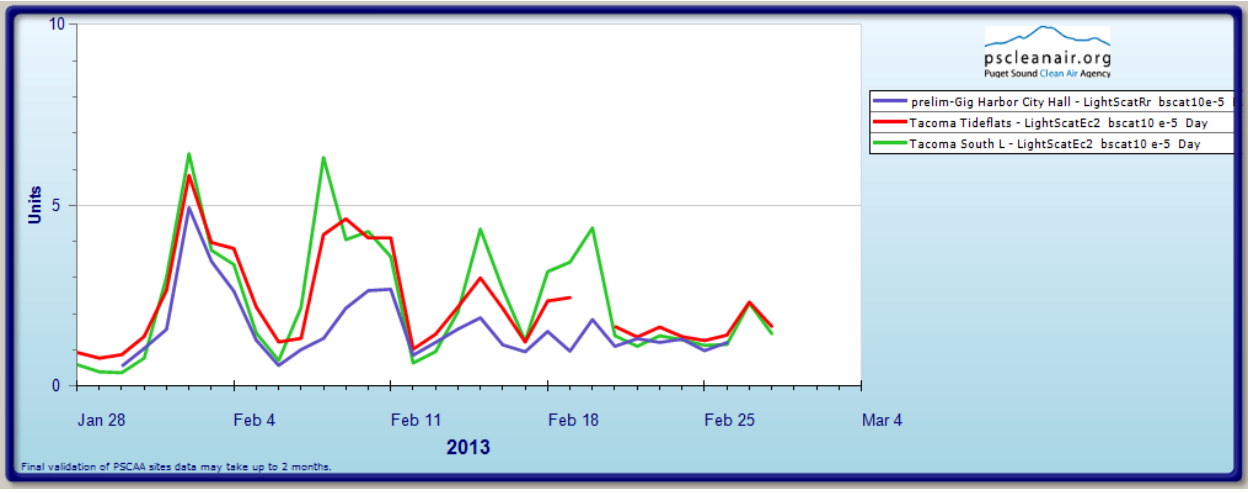

Figure 33. Gig Harbor v Tacoma Alexander and South L light scattering series.

No difference analysis was conducted for Gig Harbor, and there was not enough data to determine if the area would be at risk for exceeding the health goal.

Bonney Lake Liberty Ridge Elementary School

Bonney lake data are limited and have data quality issues. Without considering the data quality, it may appear that Bonney Lake had higher pollution levels than the rest of the fixed network in Pierce county (slopes ranging from 0.43 to 0.56 in following graphs).

The first data quality issue was the failure of the station heater. The purpose of the station heater is to maintain the shelter temperature between a range of 10 – 30 °C. The station operators documented the station heater failure on the quality control sheet, and so therefore, most likely what happened was that during most days, when shelter temperature was closer with moderate ambient temperatures, the data appeared to show that hourly values were closer to what is normally seen at fixed sites. When the cold evening temperatures dipped below 10 °C, then the nephelometer was operating too cold, and was showing biased hourly values.

The following regressions compared site TI (Bonney Lake) to the fixed sites.

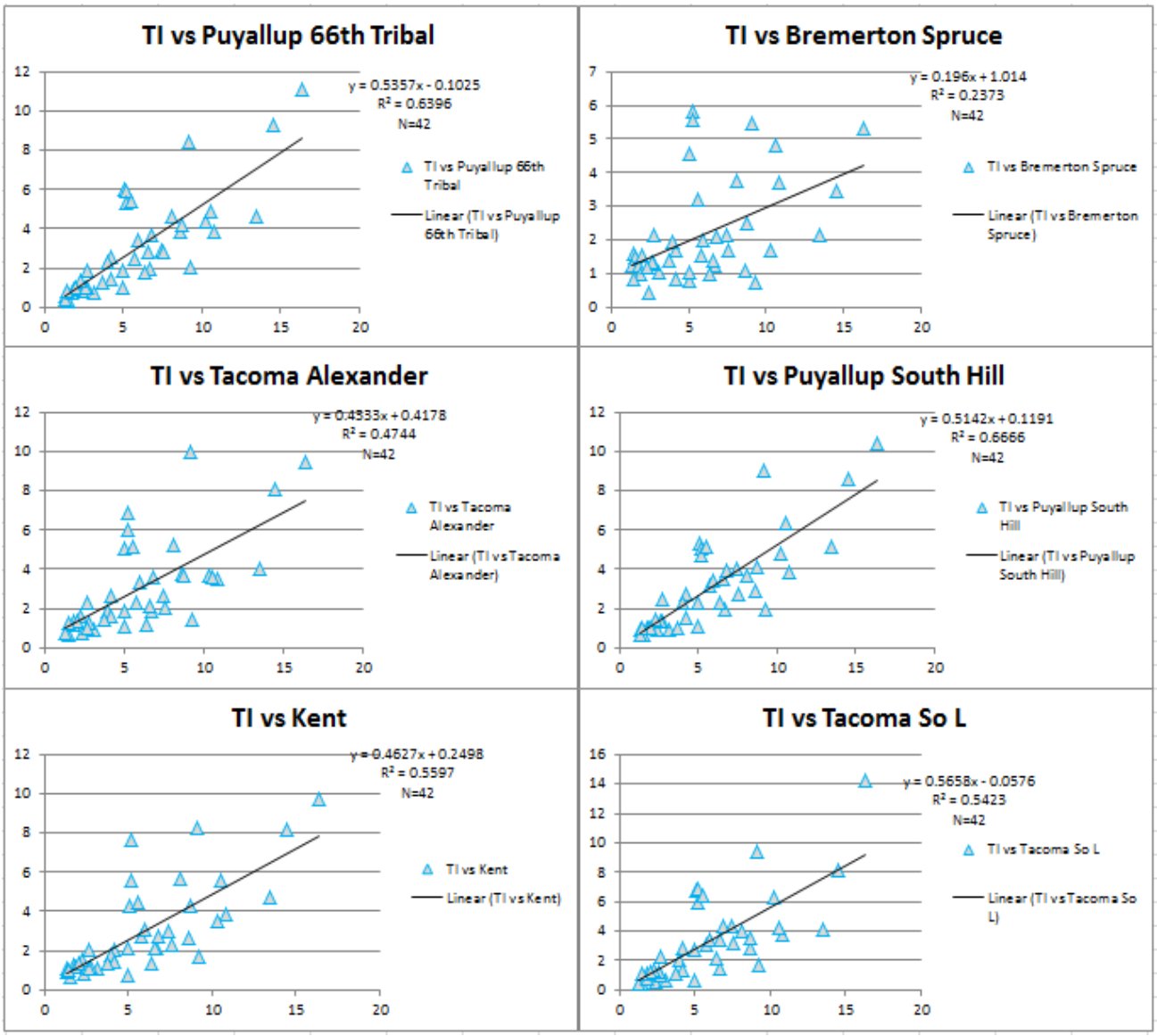

Figure 34. Bonney Lake regressions.

The second quality issue had to do with the scale of the monitoring site. The temporary stations were designed to be kept at the Neighborhood scale. Looking at the shape of the hourly data spikes, most likely the Bonney Lake site was affected by nearby chimneys. Neighborhood scale prohibits smoke sources, such as chimneys from being too close to the monitor's probe. The Bonney Lake site did have homes within 100 meters of the sampler, but at first glance, it did not appear that these homes were significant wood-burners. Most likely, one or some of these homes were burners. The Bonney Lake site was placed at the Microscale, not the Neighborhood scale. This caused hourly results to be higher than the fixed network as shown in Figure 35.

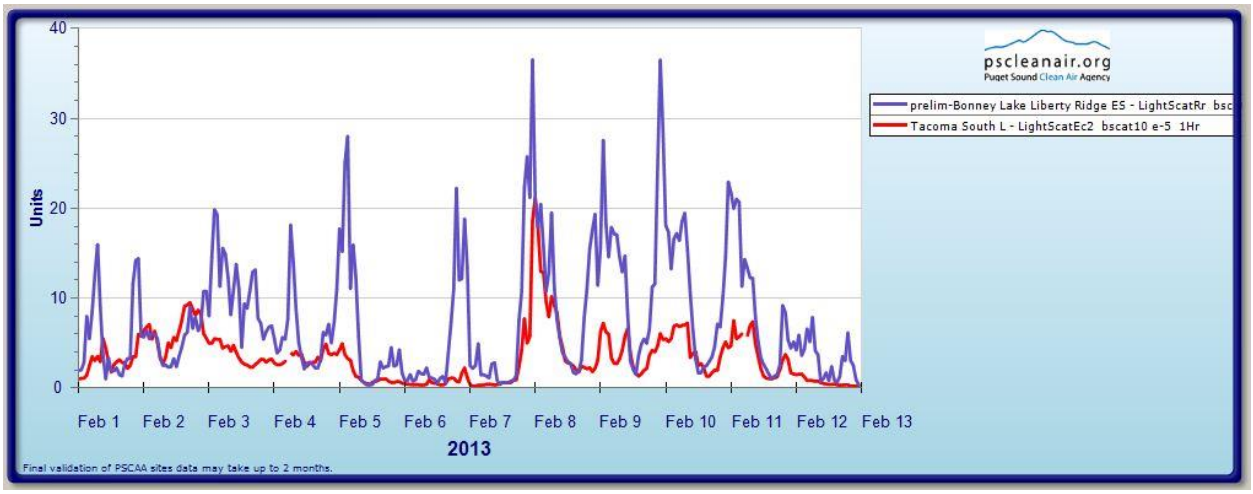

Figure 35. Hourly light scattering series for Bonney Lake v Tacoma South L.

In order to characterize Bonney Lake fine particle levels, more sampling would be needed.

Final Observations

The Agency conducted data analysis using summary statistics, regressions, difference analyses, and quality assurance precision estimates. While significant error exists in the results, based on all of the data analyzed, several observations were made.

1. Light scattering readings at the Auburn temporary sites more closely correlated with the Kent monitoring site. The light scattering levels, however, were higher than Kent, and were closer to Tacoma South L levels during the first half of the study.

2. Temporary sites that were located at a higher elevation than the closest fixed site (Kent Arbor 360 Park, Edgewood, and Graham) showed generally lower levels. This confirms our understanding of how topography affects fine particle concentrations.

3. Temporary sites in Spanaway, and Puyallup very closely correlated with other Pierce county monitoring sites.

4. The highest levels of fine particle pollution occurred at Tacoma South L, Spanaway, Auburn Pioneer, and Puyallup Maplewood stations. The temporary samplers did not show any unknown hot spots. These locations have common demographic and topographic features, such as high home density, presence of wood burners, lower elevation, and the presence of economically challenged communities.

5. Although we had a limited data set, the Gig Harbor site showed lower levels compared to other Pierce county sites. The Gig Harbor site was most closely associated with the Tacoma Alexander (Tideflats) monitor, but that association was only moderate.

6. The Bonney Lake site had shelter heater problems and was erroneously sited with regard to scale, and did not provide enough valid data to make any conclusions. More sampling would be needed to characterize Bonney Lake.

Additional data and information may be available. Please bring your questions to the Agency by contacting the Project Manager, Matt Harper at matth@pscleanair.org or (206) 689-4009.