Coal Dust Pollution in the Columbia River Gorge National Scenic Area

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Burlington Northern Santa Fe Railway (BNSF) transports coal by rail through the Columbia River Gorge National Scenic Area in open-topped coal cars. Three to four trains, each more than one mile-long, travel from the Powder River Basin (PRB) in Wyoming and Montana through the Columbia River Gorge every day. Coal discharged from nearly every coal train from the PRB pollutes lands and waters in the Columbia River Gorge. In some places, like Columbia Hills State Park in Klickitat County, coal accumulations is several inches deep on the shoreline of the Columbia River. If the Millennium Bulk Terminal proposed in Longview, Washington is built, an additional eight loaded coal trains with open coal cars would travel through the Gorge, further polluting the National Scenic Area, the Columbia River and its tributaries with toxic coal. The photos below focus on Columbia Hills State Park, just one of many sites in the Columbia River Gorge that is continuously polluted with dust and debris from passing BNSF coal trains. These photos demonstrate that the transport of coal in open rails cars has polluted and will continue to pollute the Columbia River Gorge despite the application of surfactant at the PRB mines and the installation of a surfactant re-spray facility in Pasco, Washington.

July, 2012 - Coal dust flies off a BNSF coal train into the Columbia River at Columbia Hills State Park. Photo: Julie Coop

Early 2013 – A thick layer of coal debris covered the soil in an area east of the boat launch at Columbia Hills State Park. Photo: Friends of the Columbia Gorge

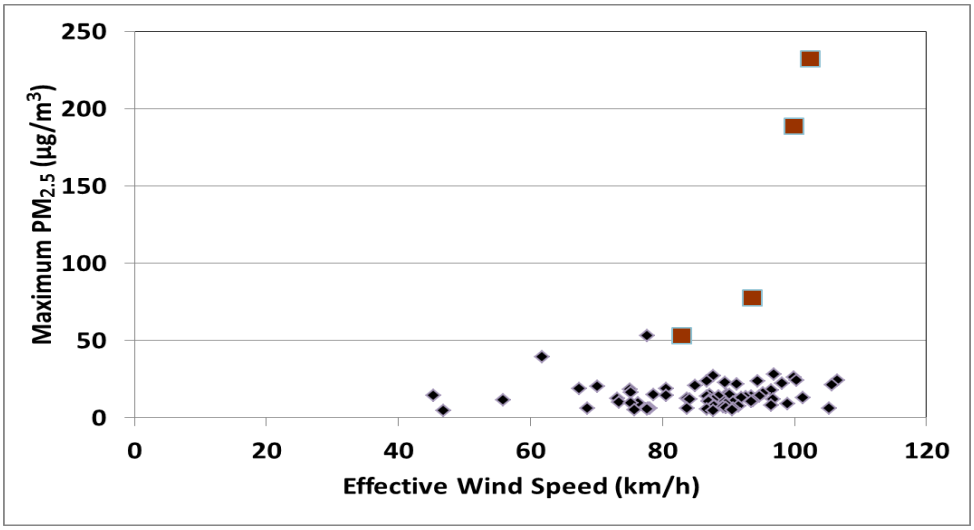
March 25, 2013 - Coal debris deposited from passing coal trains on the BNSF rail line is several inches thick along Columbia River at Columbia Hills State Park. Photo: Friends of the Columbia Gorge

March 25, 2013 - Coal debris adjacent to BNSF's railroad track along the banks of the Columbia River at Columbia Hills State Park. The U.S. Surface Transportation Board declared that coal is a "pernicious ballast foulant" that destabilizes railroad tracks and leads to more accidents.
http://www.troutmansandersenergyreport.com/wp-content/uploads/2011/03/Coal-Dust.pdf
Photo: Friends of the Columbia Gorge

August 21, 2013 - Coal several inches deep from passing coal trains on the banks of the Columbia River has replaced the soil at Columbia Hills State Park. Nothing grows here but a few invasive weeds. Coal blows directly into the Columbia River in violation of the Clean Water Act. Friends of the Columbia Gorge and its allies are currently suing BNSF for unpermitted discharge of coal into the Columbia River and other water bodies in Washington State. Photo: Friends of the Columbia Gorge

November 2015 – Dr. Dan Jaffe published a report titled "Diesel particulate matter and coal dust from trains in the Columbia River Gorge, Washington State, USA" in the Atmospheric Pollution Journal. This report monitored coal dust in the Columbia River Gorge on the BNSF rail line during the summer of 2014. The report found that nearly every coal train emits coal dust; coal trains emit double the PM 2.5 concentrations compared to other freight trains; 5.4% of coal trains emit thick clouds of coal dust; and 10.3% emit visible clouds of coal dust when the effective wind speed (the sum of the wind speed and the speed of the train) exceeds 90 kph (56 mph).
http://www.atmos.washington.edu/jaffegroup/modules/APOLLO/Jaffe_DPM_coal_dust_trains_ColumbiaRivGorge_2015.pdf

Summer 2014 - Thick plume of coal dust blows off a BNSF coal train in the Columbia River Gorge.
http://www.atmos.washington.edu/jaffegroup/modules/APOLLO/Jaffe_Video_Coal_train_Aug7_2014.mp4



One in ten coal trains emits visible plumes of coal dust at effective speeds of 90 kph (56 mph) or more.

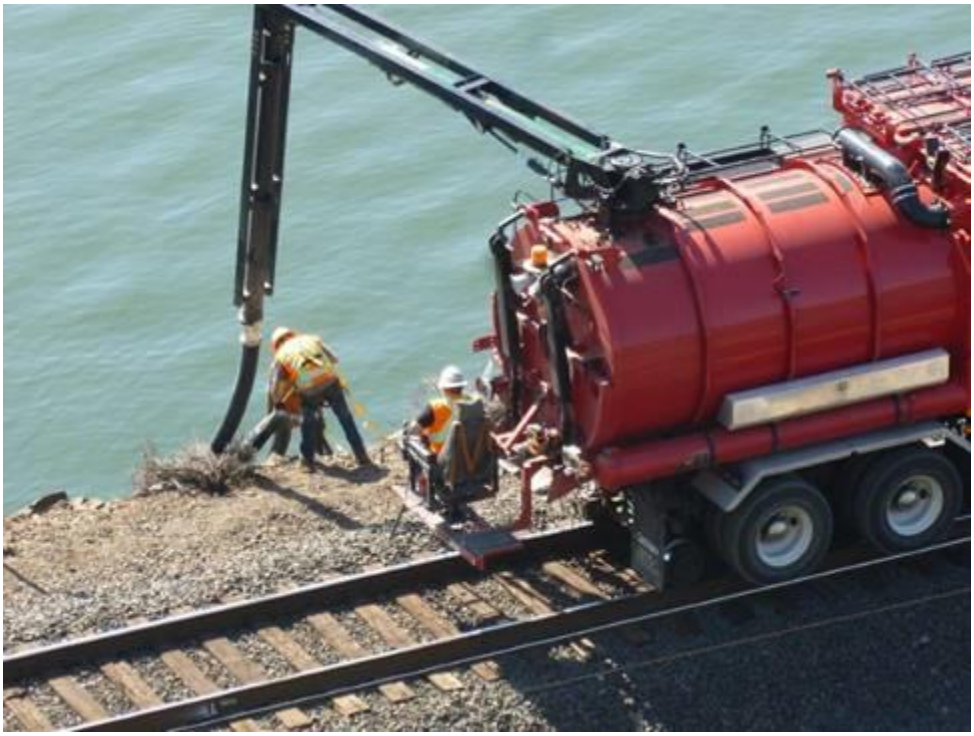
January, 2015 - BNSF began operating a re-spray facility in Pasco due to the failure of the surfactant sprayed on coal cars at the mines in the Powder River Basin to control coal dust and debris. The Tri-City Herald Newspaper also reports that BNSF treats coke trains at the facility.
https://www.youtube.com/watch?v=EYpYOfMFBAI

May 22, 2015 – Hikers at Columbia Hills State Park on the trail to the iconic petroglyph "Tsagaglalal" (She Who Watches) witnessed and photographed this passing train with black clouds of coal or coke blowing on to the state park and the Columbia River. According to the Tri-City Herald, BNSF sprays both coal and coke trains in Pasco. http://www.tri-cityherald.com/news/local/article80608512.html

May 22, 2015 – These photos of a BNSF train with what appears to be coal blowing off of coal hoppers into the Columbia River at Columbia Hills State Park several months *after* the Pasco re-spray facility became operational. Photo: Laura Foster

April 2016 – Coal dust vacuum truck at Columbia Hills State Park.

April 25, 2016 - BNSF vacuum truck removing coal debris from the banks of the Columbia River at Columbia Hills State Park. Photo: Mary Ann Teague



April 25, 2016 - BNSF contractors use a vacuum truck to attempt to remove coal debris along the BNSF track and the shoreline of the Columbia River near Horsethief Butte at Columbia Hills State Park in the Columbia River Gorge. Photo: Mary Ann Teague

April, 2016 –Photo: Friends of the Columbia Gorge

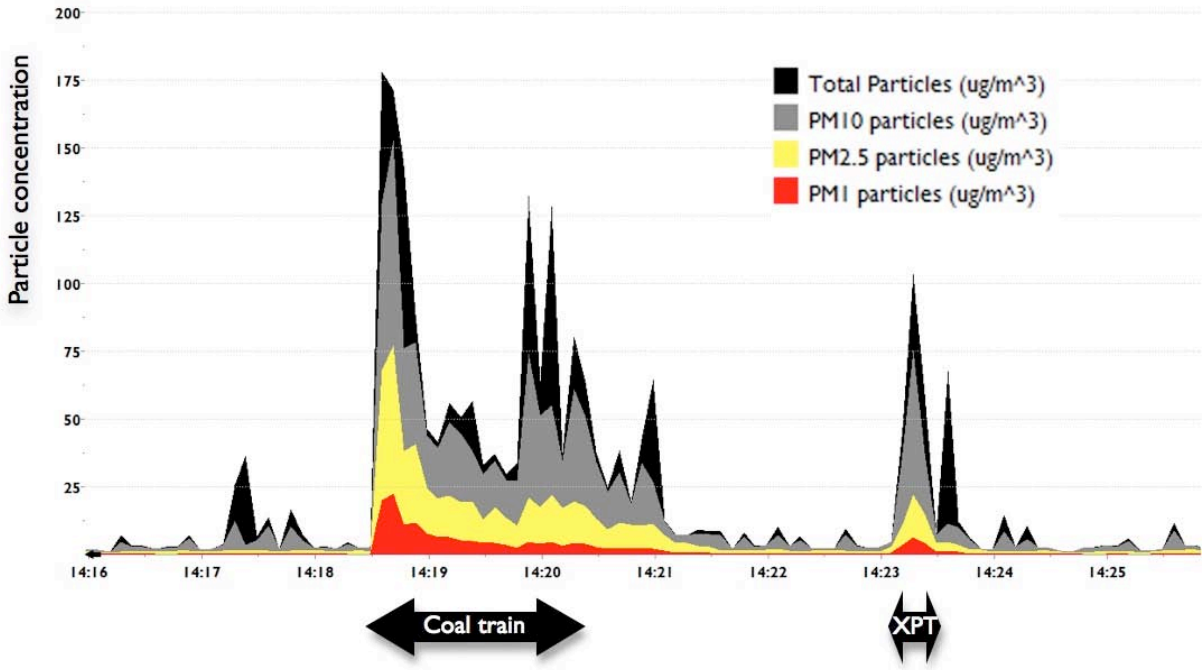
April, 2016 - The two photos above show the area directly east of the boat launch site at Columbia Hills State Park that had been recently vacuumed of coal dust and debris that routinely blows off of passing coal trains. There is still some coal dust visible in the photo. Photo: Friends of the Columbia Gorge

May 17, 2016 - BNSF vacuum truck prepares to transfer coal that was removed from the shoreline of the Columbia River to a truck for transport to the Roosevelt Regional Landfill. This site is located adjacent to the boat launch at Columbia Hills State Park. Photo: Friends of the Columbia Gorge

May 17, 2016 – Area adjacent to the boat launch, Columbia Hills State Park. Photo: Friends of the Columbia Gorge

May 17, 2016 – The three photos above show coal dust and debris accumulation in an area previously vacuumed by BNSF at Columbia Hills State Park, adjacent to the public boat launch. Coal continues to be discharged from BNSF coal trains despite the re-spray facility in Pasco, Washington that has been in operation since January 2015. Photo: Friends of the Columbia Gorge

Coal Train Pollution Signature Study



A briefing paper prepared by Associate Professor Nick Higginbotham,
Dr Ben Ewald, Ms Fee Mozeley and Dr James Whelan,

for the Coal Terminal Action Group Dust and Health Committee.

August 2013

About the Coal Terminal Action Group

An alliance of Newcastle and Hunter Valley community groups including: *The Australian Coal Alliance, Australian Youth Climate Coalition, the Barrington Gloucester Stroud Preservation Alliance, Climate Action Newcastle, Correct Planning and Consultation for Mayfield Group, Gloucester Residents in Partnership, the Green Corridor Coalition, Hunter Bird Observers Club, Hunter Community Environment Centre, Hunter Communities Network, Hunter Environment Lobby, Islington Village Community Group, the National Parks Association (Hunter Branch), the Nature Conservation Council of NSW, Parks and Playgrounds Movement, Rising Tide Newcastle, Singleton Shire Healthy Environment Group, Stockton Community Action Group, Tighes Hill Community Group, and the Wilderness Society Newcastle Branch.*

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- The members of CTAG's alliance of twenty residents, community and environment groups
- CTAG's Dus and Health Committee.
- The twenty volunteers wh assisted with the monitoring.
- More than 100 community members wh donated to make this study possible.

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Glossary

$\mu g/m^3$	micrograms per cubic metre
µm	microns (one millionth of a metre)
Entrainment	time taken for particle pollution levels to return to pre-train background levels
km	kilometre
km/hr	kilometre per hour
m	metre
m/s	metres per second
Mtpa	millio tonnes per annum
NE	northeast
NW	northwest
PM_{10}	Particulate matter with diameter of 10 micrometres or less
$PM_{2.5}$	Particulate matter with diameter of 2. micrometres or less
PM_1	Particulate matter with diameter micrometre or less
SE	southeast
SW	southwest
TSP	Total suspended particulates (with a diameter 5 micrometres or less)

Acronyms

ARTC	Australian Rail Track Corporation Ltd
BoM	Bureau o Meteorology
EPA	NSW Environmental Protection Authority
PRP	Pollution Reduction Program
OEH	NSW Office of Environment and Heritage

Executive summary

Community groups in Newcastle and the Hunter consider coal dust a significant health problem. With more than 100 coal trains passing through residential areas each day, residents have become increasingly informed about the impacts of pollution from uncovered coal wagons, and supportive of measures to reduce this pollution.

Between Monday 15 July and Wednesday 17 July, members of several community groups monitored particle pollution levels in residential areas of Beresfield, Sandgate and Mayfield. With expert advice and assistance, we monitored particle pollution concentrations while 73 loaded and unloaded coal trains passed. The Osiris equipment utilised for the study allowed for concurrent monitoring of various particle sizes: PM_1 and $PM_{2.5}$ that are associated with combustion (e.g. train locomotives) and the larger PM_{10} particles, which are indicative of coal.

The study was an initiative of the Dust and Health Committee of the Coal Terminal Action Group, an alliance of twenty community and environment groups representing residents throughout Newcastle and the Hunter Valley. The study aimed to answer two research questions:

1. What is the particulate profile (signature) of loaded and unloaded coal trains?
2. What is the increase in particulate matter associated with the passage of loaded and unloaded coal trains, measured by comparing to pre-train particle concentrations)? Is the proportion of increase the sam across al particulate fractions (PM_{10}, $PM_{2.5}$ and PM_1)?

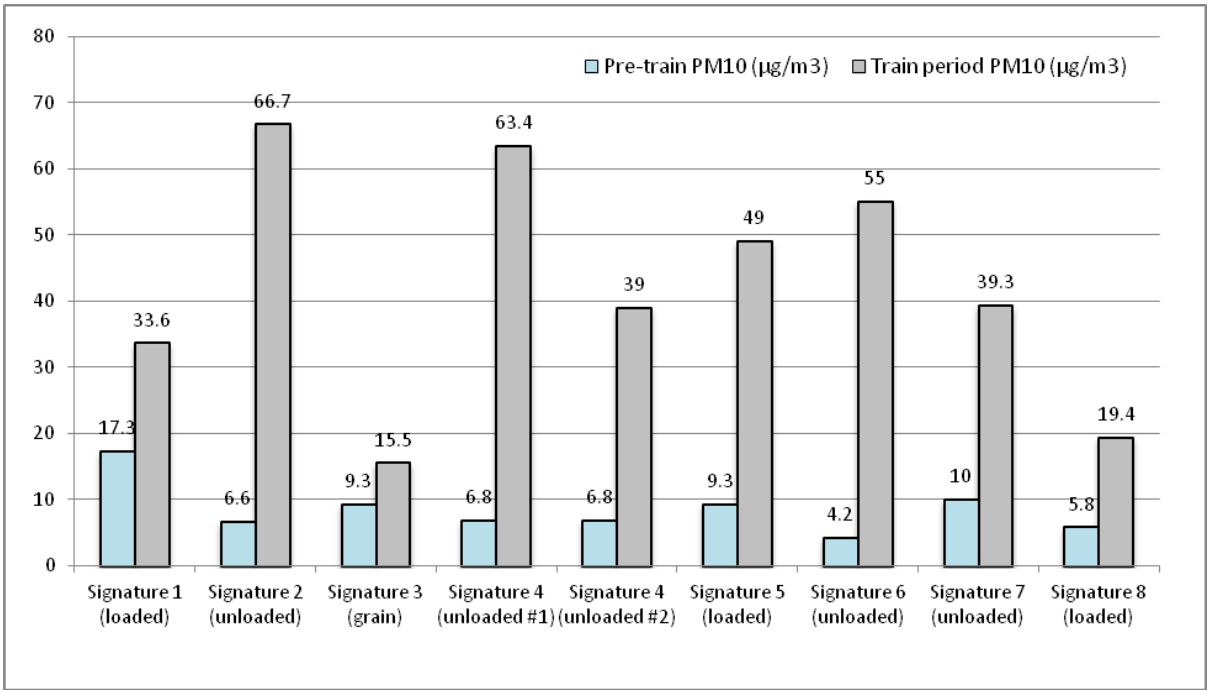
The study was the first of its kind in Australia. Crowd-funded by more than 100 donors, the study was entirely designed an conducted by members of community groups. They were advised and assisted by experts and academics an utilised industry-standard equipment. The results of the study were analyse by public health researchers.

In June 2013, before this study commenced, community members were shocked to learn that an industry stud o the particle pollution cause by coal trains had been dramatically modifie at the las momen to reverse man of its conclusions and understate the amount of pollution caused by coal trains. Unlike that study, our investigation was not designed to differentiate between train types. I deliberately focused on loaded and unloaded coal trains.

A total of 73 coal trains were observed during the three days of monitoring. The corresponding pollution data was analysed to generate 'signatures' which depict particle concentrations before, and during the trains' pass by. The method compares a two-minute average pollution level before each train to a two-minute average while the trains were passing by the monitoring equipment. Eight signatures are examined in this study. These signatures were selected to demonstrate an indicative range o signatures under various conditions (wind direction, wind speed, train speed, train type etc).

The following chart shows an analysis of particulate concentrations (PM_{10}) associated with each of the signatures. It compares 2 minutes of pre-train ai quality with 2 minute of particulate matter concentrations produced during the train passage (i.e., the signature). All graphs show coal trains, apart from Signature 3, which is a grain freight train.

Chart 1: Particulate concentrations (PM_{10} associated with train signatures



All coal train signatures were associated with a significant increase in PM_{10} particle pollution levels. In the case of Signatures 1 and 5, this represents increases of 94% and 427% respectively for loaded coal trains. Signature 6 increased PM_{10} concentrations significantly, up to 1210%. In sum, coal trains increase PM_{10} levels by between 94% and 1210%. While coal trains pass, particle pollution concentrations increase up to 1 times pre-coal train levels.

While the study wa not intended to compare different types of trains, a number of freight and passenger trains were captured in our signature measurements. We noted city link trains di not produce a definable signature, while freight trains and the XPT did show signatures in some cases, but they were much smaller in comparison to those observed for coal trains, and of shorter duration.

The results of this study warrant decisive action by the New South Wales Government. The Coal Terminal Action Group commends this study to Premier Barry O'Farrell and call on the NSW Government to:

1. Direct the state's coal industry to cover and wash all loaded and unloaded coal wagons
2. Suspend assessment of the proposed fourth coal terminal (T4)
3. Commission an independent assessment of the health impacts of particle pollutio i the Hunter to assess the social and economic impacts of current particle concentrations and model the impacts of the proposed fourth coal terminal (T4).

1. Background

Thi study was initiated and managed by the Coal Terminal Action Group's Dust and Health Committee. The committee was established in August 2012 t respond to widespread concern that Newcastle and other 'coal corridor' communities are exposed to elevated levels of fine particle pollution. Exposure is know to cause a range of serious short-term and long-term health impacts and ca occur whe pea exposures o short duration (ranging from less than an hour up to a few hours) lead to immediate physiological changes.[1]

The coal export capacity for the Port of Newcastle has grown exponentially in recent years, from 77 million tonnes per annum (Mtpa) i 1997 to 210Mtpa in 2012. The Fourth Newcastle Coal Loader (T4 proposal by Port Waratah Coal Services (PWCS) would see this increase to 330Mtpa, resulting in approximately 107 more train movements each day.[2]

NSW Health has cautioned against the development of T4 due to the impacts of existing pollution level an the modelle increases in coal dus during its construction an operation.[3] However, the coal industry and NSW Environment Protection Authority (EPA refute these health concerns, alleging that coal trains are no a significant source of fine particle pollution (nor different from other types of trains i terms of pollution) and that particle pollution diminishes rapidly with distance from the coal corridor. These assertions are not supported by scientific evidence.

This is CTAG's second pollution monitoring study. In late 2012, CTAG conducted air quality monitoring at twelve suburban locations to provide a snapshot of current levels of particle pollution. The alliance hired industry-standard 'Osiris' equipment to monitor particles of up to ten microns in diameter (PM_{10}) and fine particles o up to 2.5 microns and 1 micron in diameter ($PM_{2.5}$ and PM_1) in residential areas between 5 December 2012 and 5 January 2013. The study program was assisted and results analysed by air quality scientist Associat Professor Howard Bridgman and Dr Jill Sweeney of the University of Newcastle.

The results of our first study were alarming. The national standard for PM_{10} is 50 micrograms per cubic metre ($\mu g/m^3$) averaged over a 24-hour period (measured using a TEOM monitoring device). This standard was exceeded at seven locations. At some locations, we recorded levels more than 50 higher than the national standard, and the standard was exceeded a often a every day. These findings suggest that residents living within 500 metres of coal trains and stockpiles are experiencing particle pollution at harmful levels. More than 30,000 people reside and 25,000 children attend school withi 500 metres o the coa corridor betwee Rutherford and the Newcastle Port.

Building on our initial snapshot study, we embarked on a second round of air pollution monitoring to provide the community with data on PM_{10}, $PM_{2.5}$ an PM_1 'signatures' of coal trains. Such signatures show the profile of particulate pollution when repeated measurements are taken during the period when the coal train passes by. This profile reveals the upward development to the peak particulate concentrations, as well as the entrainment of suspended particulates after the train has passed, until they diminish to pre-train levels.

This second snapshot study has been designed to serv as pilot for a larger investigation into particulate emissions from coal trains.

2. Health Impacts of Air Pollution

According to the Australian Medical Association, air pollution kill more people each year in Australia than car crashes. Fine particles of ten microns or less in diameter (PM_{10}) and 2.5 microns or les in diameter ($PM_{2.5}$) are readily inhaled, causing asthma attacks, hospitalisation, reduced activity days and premature death.[4] The Australian Medical Association's President Dr Steve Hambleton recently observed that the Newcastle community already experiences high levels of pollution: "It's an especially at-risk population where we know there's already increased rates of respiratory illness."[5]

According to the NSWEPA, mining and transportation of coal contribute 87.6% of the Hunter Valley's PM_{10} and 66% of the Hunter's $PM_{2.5}$.[6] During 2012, the network of 17 Hunter Valley monitoring stations recorded levels of PM_{10} levels over the national standard on 115 occasions. Senate Committee examining the health impacts of air pollution conducted a hearing Newcastle on 16 April 2013. Many o the 150 submissions received by th Committee came from residents an community groups in the Hunter. Senators were urged to reduce air pollution by groups including the Clean Air Society of Australia and New Zealand, the CSIRO and the Australian Medical Association.[7]

There i a high level of concern about the health impacts of coal rail dust along Hunter Valley coal rail lines. For decades, residents along the coal corridor have complained about coal dust and its health impacts. On 16 March this year, 1,500 residents rallied to express these concerns and oppose a proposed fourth coal terminal.

3. Objectives

The Dust and Health Committee aims to provide the community with independent information and advice upon which to consider the T4 proposal an other port development projects. The objective of this study was to provide the community with information abou the pollutions 'signatures' of coal trains. Pollution signatures show the level of PM_{10}, $PM_{2.5}$ and PM_1 when multiple measurements are taken during the period when a coal train passes by a monitoring point. This profile reveals the upward development to the peak particulate concentrations, as well as the 'entrainment' of suspended particulates after the train has passed, until they diminish to pre-train levels.

4. Method

4.1 Research Questions

1. What is the particulate profile (signature) of a coal train pass-by (loaded and unloaded) as measured by concentrations of PM_{10} $PM_{2.5}$ and PM_1?

2. What is the increase i particulate matter associated with the passage of loaded and unloaded coal trains, measured by comparing two minutes averages, starting three minutes before the train arrives, two minutes averages starting 30 seconds after the train arrives? Is the proportion of increase the same across all particulate fractions (i.e., PM_{10} vs $PM_{2.5}$ vs PM_1)?

4.2 Site selection

Criteria fo selecting monitoring sites

- Proximity to frequent coal train movements
- Proximity to residential areas
- Sites close t and o downwind side of tracks for optimum capture of PM fraction
- Ability to respond to wind and weather conditions
- Clear of environmental interferences such as trees, houses, localised sources of PM and
- Access to power sources and security.

Selected monitoring sites

- Beresfield train station
- Hexham – near the Shamrock Street crossing
- Waratah train station
- Upfold Street Mayfield

map showing these four locations is available online here > https://www.google.com/maps/ms?msid=210722871585608627393.0004de7533379370e3362&msa=0

Further monitoring requirements

- Calibration at EPA's TOEM monitoring site at Francis Greenway High School, Beresfield
- Log keeping capturing variables - particularly train movements and also non-target events to help explain changes in PM levels.

4.3 Monitoring duration and techniques

The monitoring equipment was positioned according to the manufacturers' specifications. Mike Fry, the Managing Director of Turnkey Instruments Pty Ltd that hires thi equipment to industry and government throughout Australia, oversaw all aspects related to the setting up the monitors and data management. Monitors were set up downwind of the coal tracks to capture emissions from rail trains.

To address the research questions, the monitoring was conducted a close t coal track lines as possible and the monitor was kept i place as long as practicable to capture background air levels and concentrations of particulate pollution specifically from loaded and unloaded coal train movements.

Volunteers received training and supervision in recording log information about the train pass-bys.

Estimating train speed

Train speed was calculated with a stopwatch. Th time taken for the passing of 1 car was recorded and then used to analyse the approximate train speed. Time keepers were reminded that the starting point is gap zero, not car one. Time keepers were instructed to look across the train to the landscape behind (flashes visible in the space between cars) and to choose a flash to start the watch, and count "zero", 1, 2 etc and stop the watch at 10.

Researc team tasks

The monitoring required three researchers. Two researchers logged the train detail on a recording sheet. The third researcher assiste Mike Fry to ensure that the monitor was functioning during the pass-by recording, and noted any anomalous readings. These were noted and any immediate sources identified, if present. This researcher also noted the imminent arrival of a second train passing by when that occurred, so the person logging recorded its passage accurately.

Log sheets recorded start time, stop time, type of train (loaded coal, unloaded coal, freight, passenger), number of locomotives, number of wagons or carriages, train code and company, time for 10 carriages to pass, and multiple or single pass-by.

4.4 Equipment

Osiris air quality monitors were hired from Turnkey Instruments. These instruments are capable of simultaneously measuring Total Suspended Particles (TSP), PM_{10}, $PM_{2.5}$ and PM_1 particulates. The equipment can be set to monitor every one second or every ten seconds with the results saved to memory or immediately transmitted in selected timing averages. Once down-loaded, the stored data wa then interpreted using the AirQ32 software which generates trending graphs, tables, and win inputs. These can also be represented as a pollution rose to indicate the wind direction that the particulates travelled from towards the sampling location at the time of measurement.

4.5 Review Process

Our analysis and conclusions were independently reviewed by Associate Professor Howard Bridgman, one of Australia's leading air quality experts and editor of the Clean Air Society of Australia and Ne Zealand journal. Independent review was considered of utmost importance following the controversial Australian Rail Track Corporation report published in June 2013. Two weeks after the ARTC report was published, and after the NSW EPA announced their policy response to the report, an independent review by Dr Luke Knibbs of the University of Queensland highlighted fundamental flaws in the study and its analysis.

5. Data analysis and findings

5.1 Osiris versus TEOM

Before undertaking trackside monitoring the Osiris air monitors were positioned nex t the permanent EPA monitor at Beresfield on Monday 15 July and set to record minute average of PM_{10} and $PM_{2.5}$, as these are the parameters recorded by the EPA TEOM device that is regarded as industry standard. This wa done for 29 minute to calibrate th Osiris instrument to the EPA's monitoring of background particle concentrations.

µg/m^3	TEO PM_{10}	Osiris PM_{10}	TEO $PM_{2.5}$	Osiris $PM_{2.5}$
Average	19.910	11.417	13.356	5.307
Standard deviation	3.322	1.742	1.462	0.401

The correlation between Osiris readings an TEO for PM_{10} was r=0.676, and for $PM_{2.5}$ was r=0.838, showing that the readings are fairly highly correlated, and that Osiris readings were lower for PM_{10} by about 40% and for $PM_{2.5}$ by about 60%. Regression of Osiris against TEOM showed that for PM_{10} TEOM = 5. + Osiris x 1.28 and for $PM_{2.5}$ TEOM = -2.87 + Osiris x 3.06.

5.2 Location specifications

For the remainder of the day on Monday 15 July, the Osiris monitor was then mounted 0.8m from the fenced perimeter of the railway corridor at Beresfield. Weather conditions were partly cloudy, mostly dry, with light intermittent wind from the north-west, average wind speed 0.2m/s. The Osiris was run from a small portable generator on a 15m extension lead, which was positioned to the south west, downwind from the monitor. The distances to the rail tracks were 8.6m, 12.3m, 17.3m and 23.0 from the mid-line of the tracks for the coal outbound, coal inbound, passenger outbound and passenger inbound lines respectively. Empty coal trains travelled on the nearest track, and full coal trains on the second nearest track.

On Tuesday 16 July, the Osiris monitor was mounted 0.5m from the fenced perimeter of the railway corridor at Hexham near the Shamrock Street crossing. Weather conditions were partly cloudy in the morning becoming sunny as th day progressed. Condition were dry. Th average wind speed was 1.3m/s with the 75th percentile of wind speed registering 2m/s with a maximum wind speed of 5m/s. The Osiris was run from a small portable generator on a 15m extension lead, which was positioned to the east-northeast, downwind from the monitor. The monitor was located 12m from the inbound coal track and 9m from the inbound passenger train track. The distances to the rail tracks were 27.6m, 23.3m, 19.3m and 15.0m from the mid-line of th tracks for the unloaded coal outbound, loaded coal inbound, passenger outbound and passenger inbound lines respectively.

On Wednesday 17 July, the Osiris monitor was again mounted 0.8m from the fenced perimeter of the railway corridor at Beresfield. Weather conditions were sunny and dry, with light intermittent wind from the NW, with an average wind speed 1.02m/s. Location details including distances from the track were the same as Monday 1 July (see above).

5.3 Data Analysis and Findings

Pollution Signatures

Tw technical observers independently assessed graphics of each train pass-by to assess whether it produced a distinguishable signature. Signatures were confirmed for trains that measured a clear rise in particulate concentrations (TSP, PM_{10}, $PM_{2.5}$ and PM_1) compared to the background air prior to and after the train pass-by. Bot assessors agreed that more than 80 of coa trains (loade and unloaded) showed distinguishable increases. A small number of coal trains produced a less pronounced signature, and it was increases in $PM_{2.5}$ that became a defining indicator.

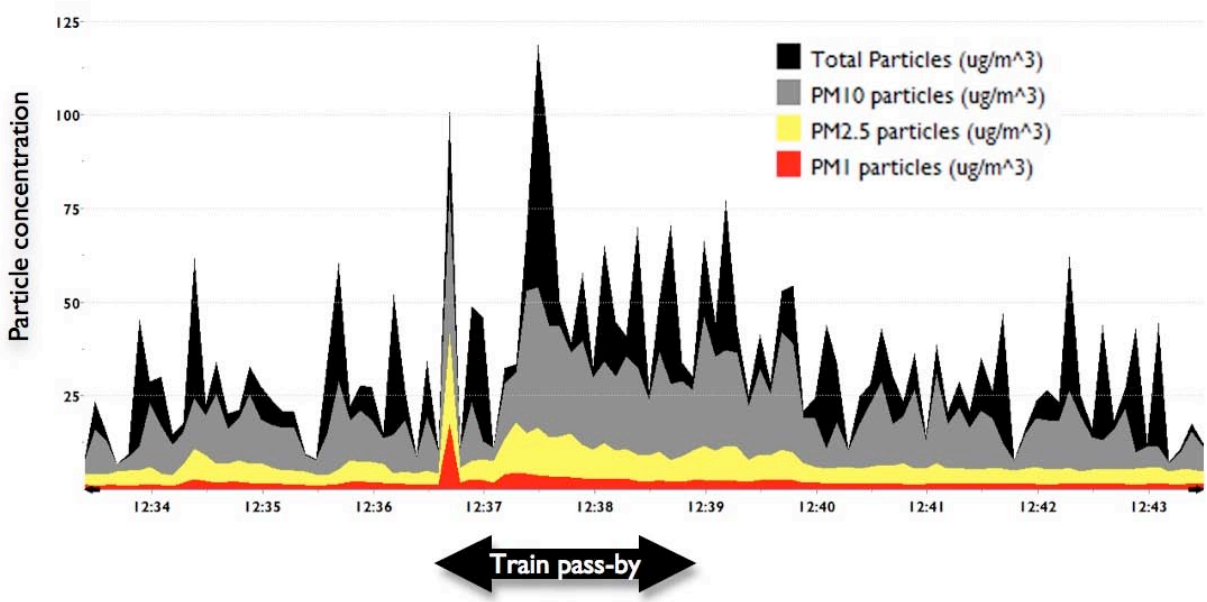
Table 1. Comparison of coal trains producing distinguishable and indistinguishable pollution signatures.

Discernible Signature	Loaded	Unloaded	Total
Yes	26 (72%)	31 (94%)	57 (81%)
No	10 (28%)	3 (6%)	13 (19%)
Totals	36	33	7 (100%)

Note: Further analysis will be undertaken to understand the significance of non-signature producing trains.

The following eight graphs provide an indication of the nature and possible determinants of train pollution signatures.

Figure 1 Signature 1 - Loaded Coal Train Monday 12:36pm



Signature 1 shows a characteristic loaded coa train (3 locomotives and 100 wagons) signature during monitoring. The train pass-by coincided with a brief wind blast of 3.6km/hr that was preceded and followed by relative stillness. The train slowed upon arrival to pass at an average of 42km/hr.

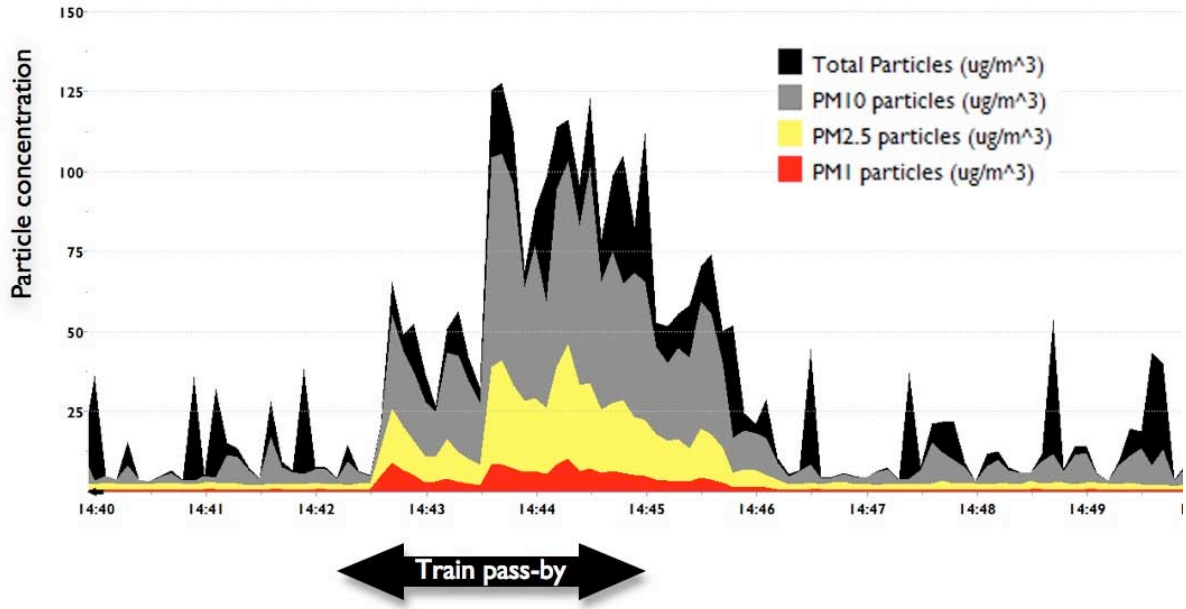
The loaded coal train produced a sharp rise in concentrations of all particulate sizes and produced an entrainment that lasted more than four minutes. This signature stands out against background track air that had residual pollution from an earlier train tha ha passed by less than two minutes prior.

The short burst of PM_1 $PM_{2.5}$ and PM_{10} at the onset of the pass by is remarkable. The high ratio of PM_1 to TSP indicates diesel emissions and i positively correlated with the logge observations that noted that this train was producing 'heavy smoke' from the locomotives.

Thi signature shows continuing high proportions of PM_{10} to TSP, with a gradual decline in $PM_{2.5}$, and a slow return to pre-train background levels. PM_{10} was 33.6µg/m^3 averaged over two minutes and pre-train background PM_{10} levels were 17.3µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 1.	17.3µg/m^3	33.6µg/m^3	16.3µg/m^3

Figure 2. Signature 2 - Unloaded Coal Train Monday 14:42pm

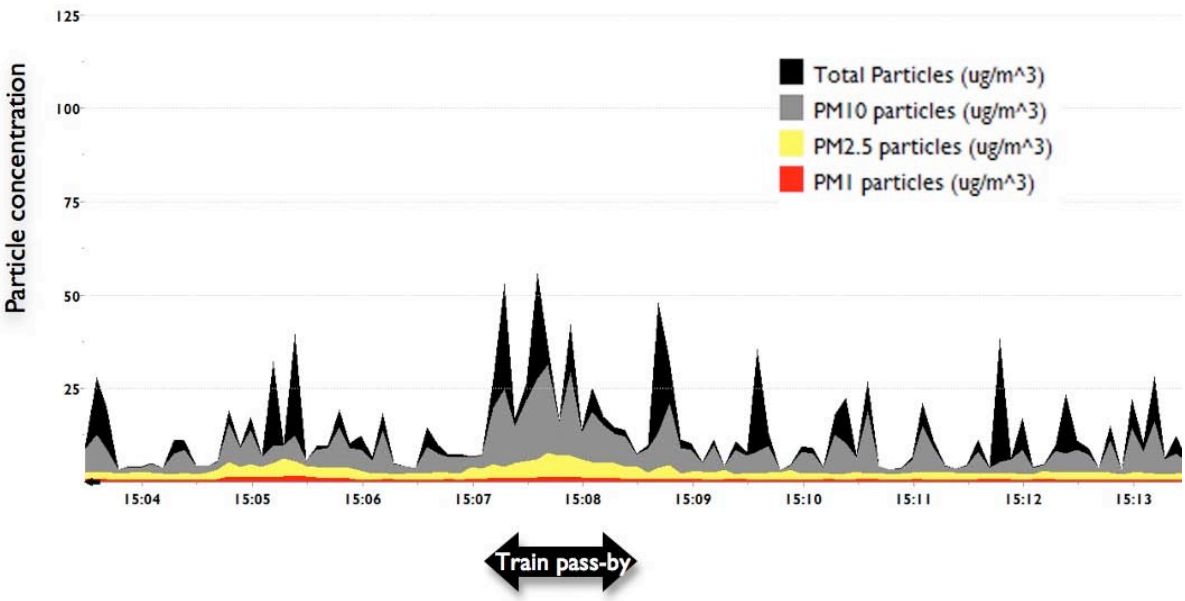


Signature 2 i indicative of an unloaded coal train pass-by. The track for this unloaded coal train was the closest to the Osiris monitor. Unloaded coal trains generally approached the monitor a higher speeds than loaded coal trains. Thi unloaded coal train (with 3 locomotives and 98 wagons) slowed to an average speed of 35km/hr. Th wind was moving a 0.13km/hr and turned from N to the direction of the train, which was SE/SSE during the pass-by.

Thi signature shows two initial spikes in particulate matter with a one minute delay and then a third, larger and more sustained pollution plume. Signature shows strong indication of diesel emissions (PM_1 and strong $PM_{2.5}$ level accompanying th high levels of PM_{10} The two-minute average o PM_{10} was 66.7µg/m^3 compared to the two minute average pre-train level of 6.6µg/m^3 An entrainment of more than four minutes is noted.

Pollution Signature	Pre-trai period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 2.	6.6µg/m^3	66.7µg/m^3	60.1µg/m^3

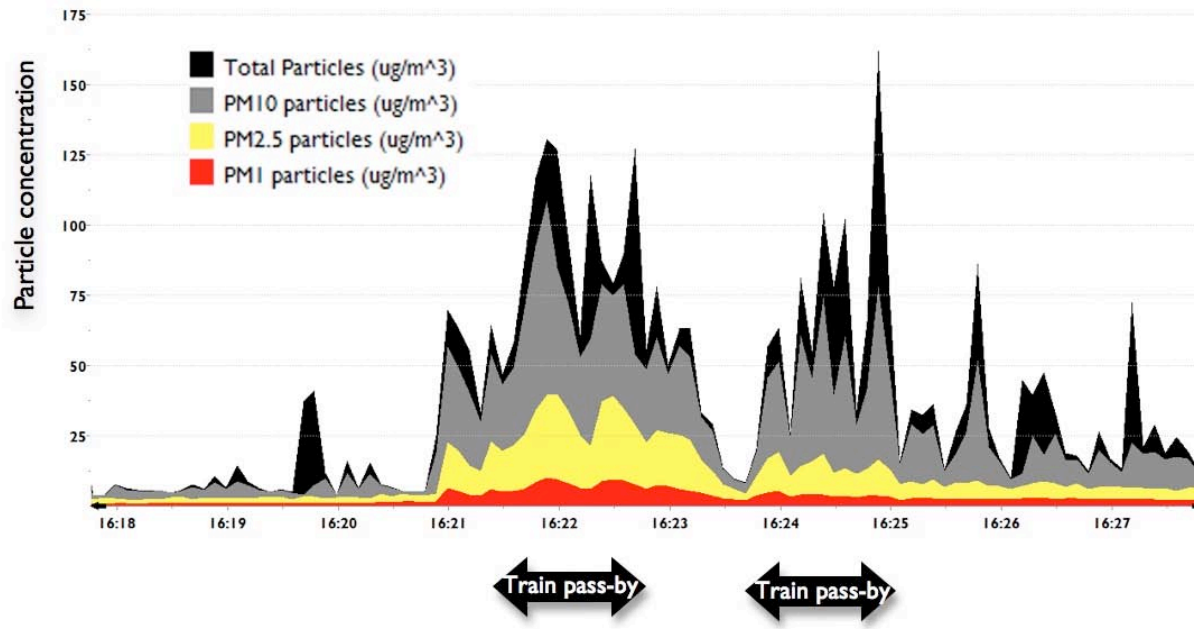
Figure 3. Signature 3 – Grain Train Monday 15:07pm



Signature 3 represents the affects of a freight train carrying grain. This AWB grain train (with 4 locomotives and 36 enclosed wagons) was travelling on the track closest to monitor. The train was moving at an average speed of 31km/hr. The air was still and the blast of air that accompanied the train changed the wind direction from NNE to SE during the pass-by. It gives a modest signature against the background, with two-minute average PM_{10} levels of 15.5µg/m^3 and averag pre-train background levels of 9.3µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 3.	9.3µg/m^3	15.5µg/m^3	6.2 µg/m^3

Figure 4. Signature 4 – Multiple Unloaded Coal Trains Monday 16:21pm

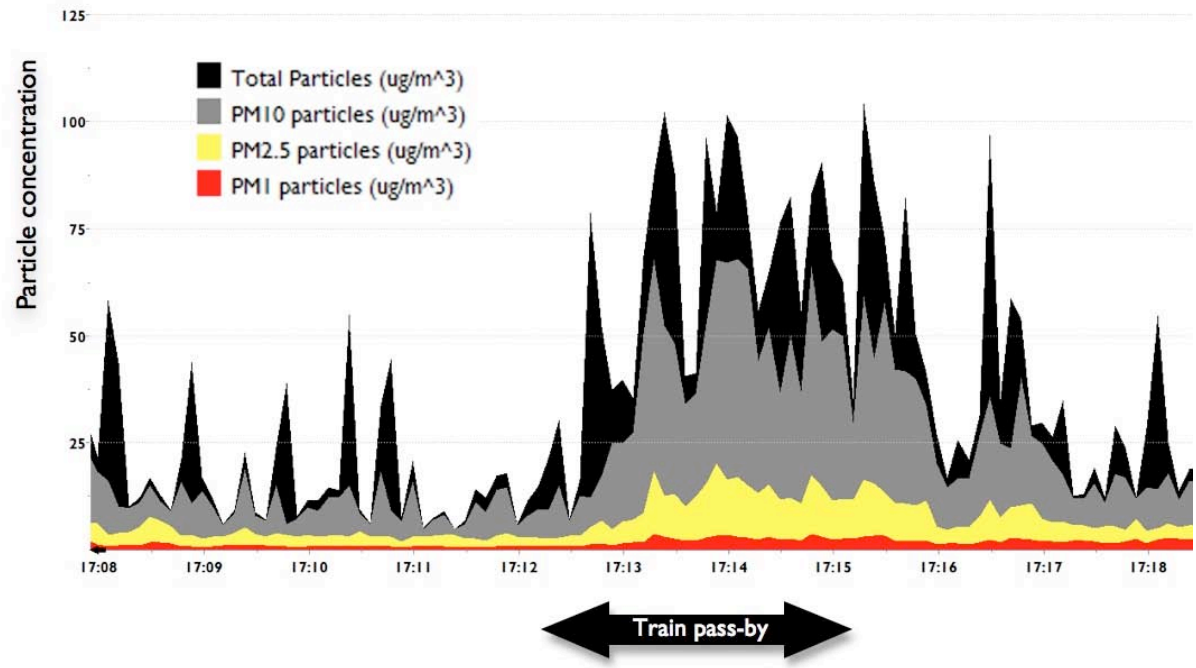


Signature 4 captures two back-to-back unloaded coal trains. The first unloaded coal train (3 locomotives an 10 wagons) approached at 69km/hr and then slowe to an average spee of 40km/hr. The second unloaded coal train (2 locomotives and 72 wagons) passed by at a constant speed of 67-68km/hr. The combination of the two trains generated their own wind, increasing from 1.9 to 4.3km/hr (ESE).

The signature shows high levels of TSP containing PM_{10} and high initial levels of $PM_{2.5}$ that is slow to diminish. The first train PM_{10} leve was 63.4µg/m^3 while the pre-train leve was 6.8µg/m^3. The second train measured an average PM_{10} leve o 39µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 4. Train 1	6.8µg/m^3	63.4µg/m^3	56.6µg/m^3
Signature 4. Train 2	6.8µg/m^3	39µg/m^3	32.2µg/m^3

Figure 5. Signature 5 – Loaded Coal Train Monday 5:12pm

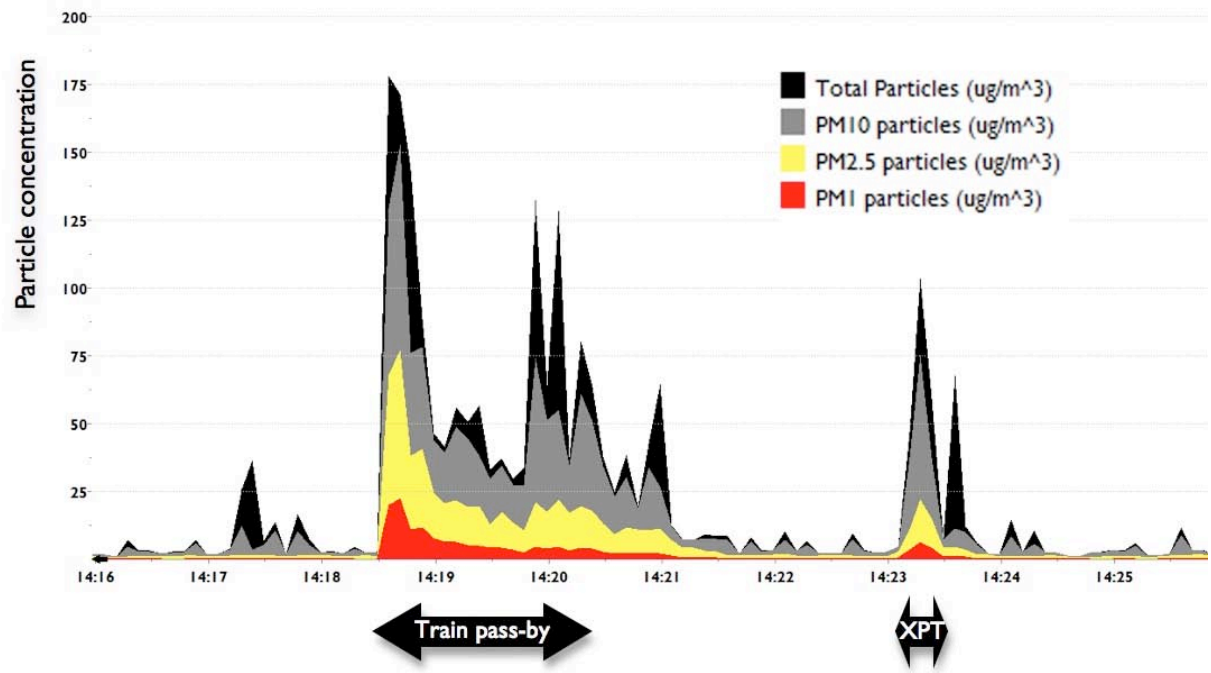


Signature 5 show a loaded train (locomotives and 9 wagons) travelling at an average speed of 29km/hr. The wind speed was 0.7km/hr from the NNW, following the train. This signature was capture a the end of the first day of monitoring. Wind conditions were very still. The loaded coal signature is eviden against increased background pollution levels from previous trains.

Thi signature shows a delay in plume arrival carrying a large proportion of PM_{10} with a long entrainment. A 30 second gap was added to adjust for plume delay, two minute average of train pass-by measured PM_{10} a 49µg/m^3 and two minute average for pre-train background levels at 9.3µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 5.	9.3µg/m^3	49µg/m^3	39.7µg/m^3

Figure 6. Signature 6 – Unloaded Coal Train Tuesday 2:18pm



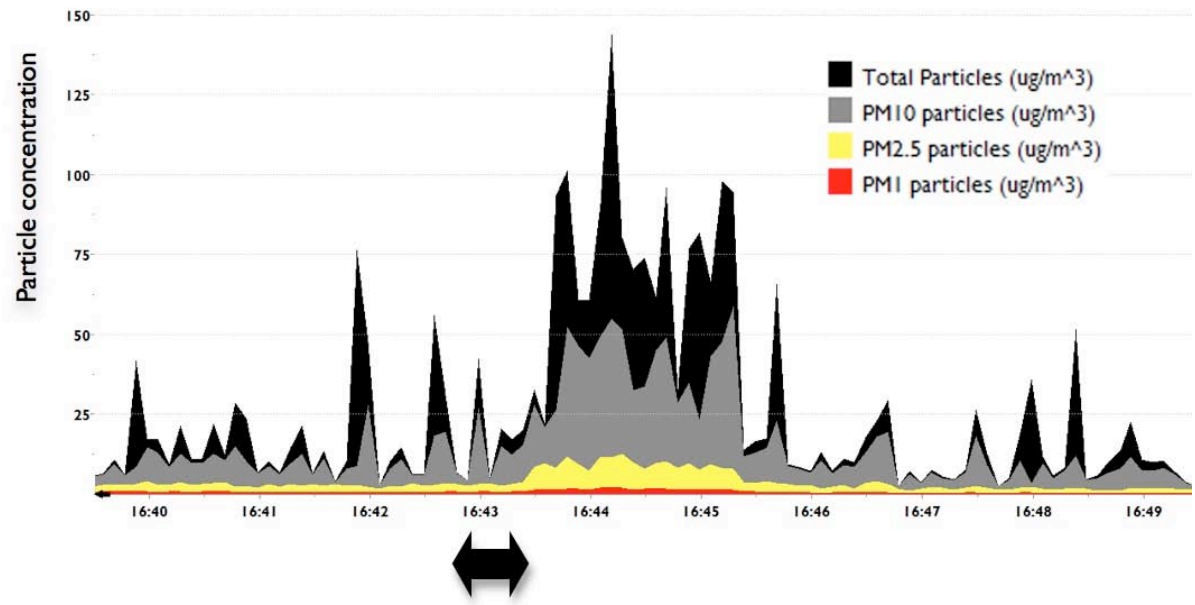
Signature 6 was termed the 'Midnight Oil' signature by an atmospheric scientist in honor of the band's 1987 hit album 'Diesel and Dust'. The unloaded coal train (3 locomotives an 82 wagons) approached the monitoring site travelling at 59km/hr and was heading into NW 7.9km/hr wind. Logged observations noted that billowing smoke could be seen from the locomotives a the train approached and that the smell of diesel was distinguishable at the onset of the train pass-by.

The signature shows that the initial plume contained high concentration of PM_1 indicating diesel combustion. The win speed was significantly stronger and thi may accoun for the absenc of a delay in the arrival of the initial pollution plume an als for the rapid dispersion of particulates back to baseline in less than three minutes. Averag PM_{10} for the train pass-by was measured as 55µg/m^3 and pre-train average was 4.2µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 6.	4.2µg/m^3	55µg/m^3	50.8µg/m^3

In the wake of the 'Midnight Oil' train described above, a fas movin XPT CountryLink train was captured. This train produced a clear signature of very short duration, evident toward the right side of figure 6 above. This signature show a diesel combustion spike an high proportion of PM_{10}, followed by a secon short dust burst.

Figure 7. Signature 7 – Unloaded Coal Train Tuesday 16:42pm

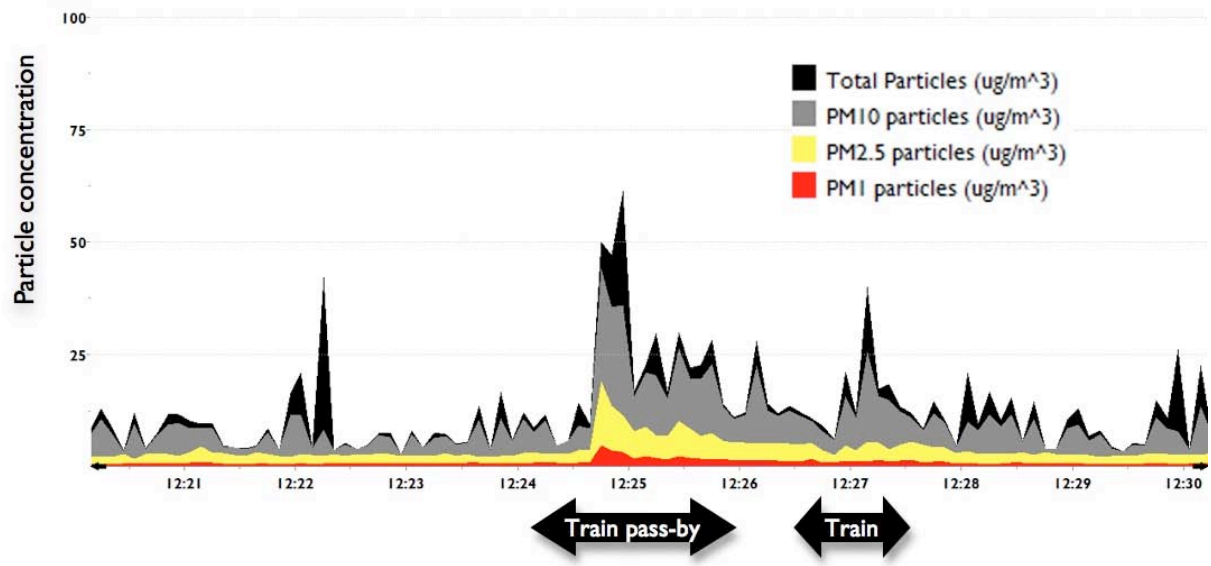


Signature 7 corresponds to a fast unloaded coal train (2 locomotives and 3 wagons) captured at Hexham on Tuesday. Initial train speed was calculated as 71km/hr with an average pass-by speed of 57km/hr. There was no win during the pass-by.

The signature shows that the train ha almost completely passed by before the pollution plume registered. The signature depicts high levels of PM_{10} and TSP and shows a relativel fast return to baseline levels. Two-minute averages of PM_{10} during train pass-by were measured as 39.3µg/m^3 and two minute pre-train background PM_{10} levels were 10µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 7.	10µg/m^3	39.3µg/m^3	29.3µg/m^3

Figure 8. Signature 8 – Loaded Coal and Freight Trains Wednesday 12:24pm



Signature 8 is a loaded coal train (3 locomotives and 96 wagons) captured at Beresfield on Wednesday. This train moved at a stead pace averaging 46km/hr. Wind speed was 4.4km/hr and followed the train from a NNW direction.

This signature i modest. TSP peaks at 63µg/m^3. High concentrations of PM_{10} are observed and there is clear rise i PM_1 and $PM_{2.5}$ A 30 second gap was added to adjust for plume delay, two minute average o train pass-by measured PM_{10} at 19.4µg/m^3 and two minute averag for pre-train background levels at 5.8µg/m^3.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 8.	5.8µg/m^3	19.4µg/m^3	13.6µg/m^3

Summary o signatures

All coal train signatures were associated with a significant increase in PM_{10} particle pollution levels. In the case of Signatures 1 and 5, this represents increases of 94% and 427% respectively for loaded coal trains. Signature 6 increased PM_{10} concentrations significantly, up to 1210%. In sum, coal trains increase PM_{10} level by between 94% and 1210%. While coal trains pass, particle pollution concentrations increase up to 1 times pre-coal train levels.

While the study was not intended to compare different types of trains, a number of freight and passenger trains were captured in our signature measurements. We noted city link trains did not produce a definable signature, while freight trains and the XPT did show signatures in some cases, but they were much smaller in comparison to those observed for coal trains, and of shorter duration.

The following chart and table provides a summary of PM_{10} particulate concentrations of the eight pollution signatures.

Chart 2: Particulate concentrations (PM_{10}) associated with train signatures

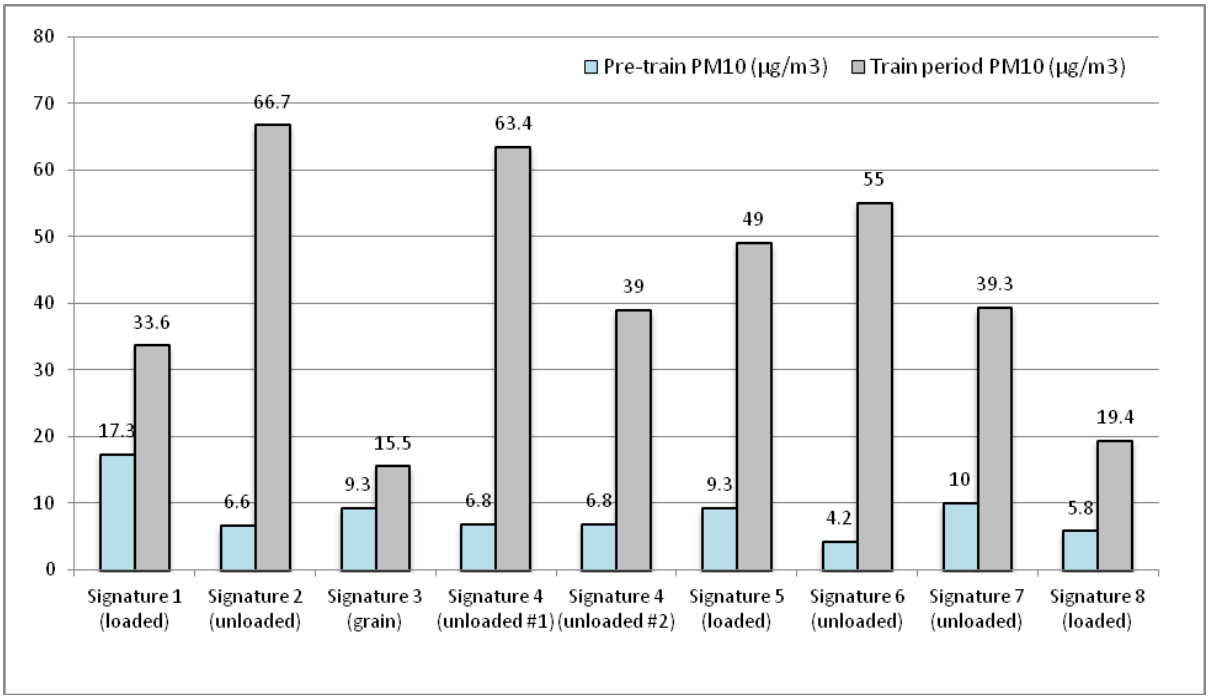


Table 6. Percentage differences of particulate concentrations (PM_{10}) associated with train signatures

Signatures	Pre-train PM_{10} (µg/m^3)	Train period PM_{10} (µg/m^3)	Difference	Difference (%)
1 – loaded	17.3	33.6	16.3	94%
2 – unloaded	6.6	66.7	60.1	911%
3 – grain	9.3	15.5	6.2	67%
4 – unloaded #1	6.8	63.4	56.6	832%
4 – unloaded #2	6.8	39	32.2	474%
5 – loaded	9.3	49	39.7	427%
6 – unloaded	4.2	55	50.8	1210%
7 – unloaded	10	39.3	29.3	293%
8 – loaded	5.8	19.4	13.6	234%

Note: The PM_{10} levels depicted above are tw minutes averages of pre-train and train pass-by and are not peak levels recorded.

Statistical analysis

The full day's data for Monday and Tuesday was examined to compare the air quality in the time before each train arrived with the air during the train's passing. The data for Wednesday is still undergoing analyses and further results will be released at a late date. Data were analysed by calculating **pre-train periods** defined as the two minutes starting three minutes before the train arrived, and **train pass-by periods** defined as the two minutes starting 30 seconds after the locomotive passed. **Trains were excluded from analysis if another train was present during the prior period** (40% did no mee criterion). The analysis was repeated with criteria for maximum allowabl average win speed during the pre-train period, however this was not consequential as there was ver light or no wind throughout the monitoring periods. All analysis was performed in Microsoft Excel except statistical testing which was performed in Stata 11.

Table 1: Full coal trains, pre-train period and train pass-by period PM_{10} in µg/m^3 for those 10 trains o 15th July where there was no other train present during the prior period.

Train time	Pre-train period (µg/m^3)	Train pass-by (µg/m^3)	Difference (µg/m^3)
12:27:11 PM	12.5	12.8	0.2
12:53:17 PM	12.9	14.9	2.0
1:40:47 PM	9.8	11.3	1.5
3:28:23 PM	6.6	34.8	28.3
3:37:05 PM	7.1	15.6	8.4
3:50:05 PM	11.5	26.1	14.6
4:03:17 PM	10.8	14.3	3.5
4:56:17 PM	12.5	21.3	8.8
5:12:17 PM	9.7	48.7	39.0
Averages	**10.38**	**22.2**	**11.81**

The average PM_{10} during the prior period was 10.38 and during the train period was 22.2 with a difference of 11.81 ($p = 0.031$, paired t test, 2 sided).

Table 2: Empty trains, pre-train period and train pass-by period PM_{10} for those 1 empty coal trains o 15th July where there was no other train present during the prior period.

Train time	Pre-train PM_{10} ($\mu g/m^3$)	Train pass-by PM_{10} ($\mu g/m^3$)	Difference ($\mu g/m^3$)
12:02:35 PM	15.2	16.9	1.7
12:12:11 PM	14.0	14.3	0.3
12:33:17 PM	10.7	17.8	7.1
1:04:17 PM	12.2	30.7	18.5
1:21:35 PM	13.3	45.9	32.6
1:54:53 PM	6.6	15.7	9.1
2:42:17 PM	6.6	66.7	60.1
2:58:17 PM	6.8	18.0	11.1
3:55:17 PM	10.7	48.2	37.5
4:21:17 PM	6.9	51.9	45.0
4:36:17 PM	6.7	30.1	23.4
Averages	**9.97**	**32.38**	**22.4**

The average PM_{10} during the prior period was 9.97$\mu g/m^3$, and during the train period was 32.38$\mu g/m^3$ with a difference of 22.41 (p=0.0032, paired t test, 2 sided).

Comparing the extra particulates associated with loaded an unloaded trains showed the mean increase was 11.78$\mu g/m^3$ (95% ci -3.51, 27.07) greater for unloaded trains although this result is not statistically significant.

Table 3: Loaded trains, prior period and train period PM_{10} and $PM_{2.5}$ for those 11 empty coal trains o 16th July where there was no other train present during the prior period.

Time	Pre-train PM_{10} $\mu g/m^3$	Train PM_{10} $\mu g/m^3$	Difference $\mu g/m^3$	Pre-train $PM_{2.5}$ $\mu g/m^3$	Train $PM_{2.5}$ $\mu g/m^3$	Difference $\mu g/m^3$
9:24:01 AM	22.6	24.5	1.9	7.6	9.3	1.7
10:09:01 AM	18.2	18.7	0.5	6.3	7.1	0.8
10:26:49 AM	16.0	22.4	6.4	5.4	7.6	2.2
11:18:47 AM	15.6	16.8	1.2	5.4	5.8	0.4
11:39:17 AM	18.9	20.7	1.7	5.2	5.6	0.5
11:55:47 AM	11.7	15.0	3.3	4.2	5.3	1.1
12:12:29 PM	8.8	14.1	5.3	3.1	5.4	2.3
1:00:11 PM	9.9	21.8	11.9	3.1	7.1	4.1
1:20:35 PM	6.4	8.6	2.1	2.6	3.4	0.8
3:16:41 PM	3.1	10.6	7.5	1.2	3.3	2.1
3:31:11 PM	5.2	32.2	27.0	1.8	13.3	11.5
3:56:23 PM	6.4	22.8	16.4	2.1	10.3	8.2
4:11:59 PM	11.3	20.3	9.0	3.7	6.3	2.6
Averages	**11.9**	**19.1**	**7.2**	**4.0**	**6.9**	**2.9**

The average PM_{10} during the pre-train period was 11.9µg/m^3, and during the train period was 19.1µg/m^3, with a difference o 7.2µg/m^3. The average $PM_{2.5}$ during the pre-train period was 4.0µg/m^3 and during the train period was 6.9µg/m^3, with a difference of 2.9µg/m^3.

Table 4: Unloaded trains, prior period and train period PM_{10} and $PM_{2.5}$ for those 1 empty coal trains o 16th July where there was no other train present during the prior period.

Time	**Pre-train PM_{10} (µg/m^3)**	**Train PM_{10} (µg/m^3)**	**Difference (µg/m^3)**	**Pre-train $PM_{2.5}$ (µg/m^3)**	**Train $PM_{2.5}$ (µg/m^3)**	**Difference (µg/m^3)**
10:40:43 AM	11.1	25.6	14.5	4.8	11.4	6.6
11:00:59 AM	18.0	26.0	8.1	6.0	9.9	3.9
12:59:59 PM	9.4	22.0	12.6	3.0	7.2	4.2
1:28:23 PM	8.0	15.0	7.0	2.8	7.3	4.5
2:04:17 PM	2.8	18.9	16.1	1.1	5.4	4.3
2:18:29 PM	4.2	39.2	35.0	1.3	15.9	14.6
2:29:11 PM	3.0	22.4	19.4	1.3	8.0	6.7
3:22:41 PM	4.0	7.0	3.0	1.3	2.9	1.6
3:51:59 PM	4.1	35.3	31.1	1.4	17.6	16.1
4:02:53 PM	5.1	37.4	32.3	1.6	10.7	9.0
4:42:47 PM	10.0	39.3	29.2	2.9	9.2	6.3
Average	**7.3**	**26.2**	**18.9**	**2.5**	**9.6**	**7.1**

The average PM_{10} during the pre-train period was 7.3µg/m^3 and during the train period was 26.2µg/m^3, with a difference of 18.9µg/m^3 The average $PM_{2.5}$ during the pre-train period was 2.5µg/m^3 and during the train period was 9.6µg/m^3, with a difference of 7.1µg/m^3.

6. Conclusions

Thi study found that 80 of coal trains produced a recognisable pollution signature. The signatures compromise a sharp rise in TSP, PM_{10}, $PM_{2.5}$ and PM_1 particulates, lasting 3.5 to 5 minutes. They show initial bursts o ultrafine PM_1 and fine $PM_{2.5}$ particulates indicating diesel combustion and chemical reaction processes. The ultrafine and fin particulates are contained within larger spike of dust, mostly PM_{10} the size associated with coal dust. Signature magnitude was seen to be influenced by factors such as wind speed and direction, train speed and distance from the monitor. The analysis of two minute segments of these signatures showed that PM_{10} levels were at least double pre-train particulate levels, and ranged up to 13 times larger.

Statistical analysis was performed on 60% of coal trains that met the inclusion criteria (i.e., no other train movement three minutes prior to arrival of the coal train). Analysis involved comparison of two minute pre-train background air quality with two minutes of train pass-by particulates. The results demonstrate a clearly measurable an statisticall significant increase i particulate pollution during the time that coal trains passes through residential areas.

The results from the Osiris device used showed acceptable correlation to the reference TEOM but did not record identical particle concentrations. Applying a conversion equation to the Monday measurements would indicate an average increase of 18.8µg/m^3 for full trains and 33.9µg/m^3 for empty trains.

Incremental additions of ai pollution of this magnitude into the airshed can add up to a large health problem, as everyone in the population is exposed. Health effects of air pollution are well documented, even below current standards. There is probably no lower threshold for adverse effects of pollution on human health. Even short-term exposures can be harmful, especially to vulnerable people with existing disease, children and the elderly.

Further analysis of the full dataset is ongoing and those results will be forthcoming.

7. Recommendations

1. That the NSW Government directs the state's coal industry to cover and wash al coal wagons (loaded an unloaded).

2. That the NSW Government suspend assessment of the proposed fourth coal terminal (T4). Particle pollution in Newcastle and elsewhere in the Hunter already regularly exceeds the national standard and measures are urgently required to improve urban air quality.

3. An independent assessment of the health impacts of particle pollution in the Hunter must be commissioned to assess the social and economic impacts of current particle concentrations and to model the impacts of the proposed T4.

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Original article

Diesel particulate matter and coal dust from trains in the Columbia River Gorge, Washington State, USA

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ABSTRACT

We examined the emissions of diesel particulate matter (DPM) and coal dust from trains in the Columbia River Gorge (CRG) in Washington State by measuring PM_1, $PM_{2.5}$, CO_2, and black carbon (BC) during the summer of 2014. We also used video cameras to identify the train type and speed.

During the two-month period, we identified 293 freight trains and 74 coal trains that gave a $PM_{2.5}$ enhancement of more than 3.0 μg/m^3. We found an average $PM_{2.5}$ enhancements of 8.8 and 16.7 μg/m^3, respectively, for freight and coal trains. For most freight trains (52%), and a smaller fraction of coal trains (11%), we found a good correlation between $PM_{2.5}$ and CO_2. Using this correlation, we calculated a mean DPM emission factor (EF) of 1.2 gm/kg fuel consumed, with an uncertainty of 20%.

For four coal trains, the videos revealed large plumes of coal dust emanating from the uncovered coal cars. These trains also had the highest peak $PM_{2.5}$ concentrations recorded during our study (53–232 μg/m^3). Trains with visible coal dust were observed for 5.4% of all coal trains, but 10.3% when the effective wind speed was greater than 90 km/h. We also found that nearly all coal trains emit coal dust based on (1) statistically higher $PM_{2.5}$ enhancements from coal trains compared to freight trains; (2) the fact that most coal trains showed a weak correlation between $PM_{2.5}$ and CO_2, whereas most freight trains showed a strong relationship; (3) a statistically lower BC/$PM_{2.5}$ enhancement ratio for coal trains compared to freight trains; and (4) a statistically lower PM_1/$PM_{2.5}$ enhancement ratio for coal trains compared to freight trains. Our results demonstrate that, on average, passage of a diesel powered open-top coal train result in nearly twice as much respirable $PM_{2.5}$ compared to passage of a diesel-powered freight train.

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1. Introduction

Rail locomotives powered by diesel fuel travel through the Columbia River Gorge National Scenic Area as well as many urban areas in Washington State. Evaluating the air quality impacts from rail traffic for people living near rail lines is hampered by a lack of data. Several plans that would expand coal shipments by rail through Washington and Oregon to coastal ports for export to Asia have been proposed. New export facilities have been proposed for Longview and Bellingham, Washington. One proposed port near Bellingham would have the capacity to ship up to 54 million metric tons of coal annually (WA DOE, 2013).

The U.S. Department of Health and Human Services states that diesel particulate matter (DPM) is "reasonably anticipated to be a human carcinogen" (U.S. DHHS, 2014). The World Health Organization also categorizes DPM as "carcinogenic to humans" (WHO, 2012). In urban areas, including Seattle, the most significant "air toxic" is DPM, contributing over 80% of the cancer risk for air toxics

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(Keill and Maykut, 2003; PSCAA, 2005). DPM sources consist of rail locomotives, ships and diesel trucks, both on road and off road. Average DPM concentrations for the Seattle area are 1.4–1.9 μg/m^3, based on monitoring and a chemical mass balance model (Keill and Maykut, 2003; Maykut et al., 2003). These DPM concentrations make up 15–20% of the mass of total particulate matter with diameters less than 2.5 μm ($PM_{2.5}$).

Emission standards for new and remanufactured locomotives, developed by the U.S. Environmental Protection Agency (EPA) (40 CFR part 1033) have decreased steadily over the past several decades. For diesel locomotives various standards apply based on the date of manufacture: Tier 0, 1973–2001; Tier 1, 2002–2004; Tier 2, 2005–2010; Tier 3, 2011–2014; and Tier 4, after 2015 (U.S. EPA, 2013). Tier 4 locomotives must comply with a PM_{10} standard of 0.03 g/bhp-h, which is about 0.19 g of PM_{10} per kg of fuel consumed (U.S. EPA, 2009).

Previous studies looked at rail yards as air pollutant sources. They determined that the primary source of $PM_{2.5}$ at these sites was diesel fuel combustion. One study investigated the impact of DPM emissions on $PM_{2.5}$ concentrations at an Atlanta area rail yard (Galvis et al., 2013). Using measurements collected upwind and downwind of the rail yard, they found the average "neighborhood" contribution to $PM_{2.5}$ was 1.7 μg/m^3. The emission factors (EFs) per kg of diesel fuel burned were calculated to be 0.4–2.3 g DPM. The EFs were not determined from individual train measurements but were calculated using three different methods, each based on differing assumptions. Two studies of a Roseville, California, rail yard also found significant enhancements in $PM_{2.5}$ from the yard. Using measurements from upwind and downwind, Cahill et al. (2011) found an average $PM_{2.5}$ enhancement of 4.6 μg/m^3, and Campbell and Fujita (2006) found even larger contributions (7.2–12.2 μg/m^3). Cahill et al. (2011) also demonstrated that particles with diameters below 1 μm are the major contributor to $PM_{2.5}$ aerosol mass from diesel exhaust. Abbasi et al. (2013) studied concentrations in the interior of trains and close to rail lines and found significantly elevated $PM_{2.5}$ and PM_{10} concentrations, particularly in stations that were underground. Gehrig et al. (2007) looked at electric trains in Switzerland and examined the influence of dust from these trains on PM_{10} concentrations. Several studies investigated the EFs of on-road diesel trucks and buses (Jamriska et al., 2004; Zhu et al., 2005; Cheng et al., 2006; Park et al., 2011; Dallmann et al., 2012), but we have found no similar studies on diesel rail.

Trains that carry coal in uncovered rail cars may also release coal dust, in addition to DPM, into the atmosphere. The BNSF railway requires that a surfactant be applied over the top of coal being transported by rail (see BNSF Railway, 2013). However, we are unaware of any studies reported in the scientific literature that evaluate the efficacy of this or the impact of coal dust on air quality. By examining the PM by train type, we can examine whether there is respirable coal dust ($PM_{2.5}$) as part of the emissions from coal trains. We will also examine the particle size distribution because combustion-related particles and coal dust, which is mechanically generated, are associated with particles of different sizes (Seinfeld, 1986).

A substantial amount (44–60%) of the diesel engine $PM_{2.5}$ mass is black carbon (BC) (Bond et al., 2004; Kirchstetter and Novakov, 2007; Ramanathan and Carmichael, 2008). Because radiative forcing due to BC is the major light-absorbing species in atmospheric aerosol, it is significant both globally and regionally (Jacobson, 2001; Ramanathan and Carmichael, 2008). In addition, because of BC's surface properties, it is possible for polyaromatic hydrocarbons (PAHs) and other semi-volatile compounds to be adsorbed and transported by BC (Dachs and Eisenreich, 2000). Health organizations are also taking a hard look at BC because of its contribution to the harmful effects caused by $PM_{2.5}$, including cardiopulmonary and respiratory disease (Jansen et al., 2005; Janssen et al., 2011; U.S. EPA, 2012).

Because of the lack of information on $PM_{2.5}$ concentrations and the exposure to humans from diesel trains, the debate over coal dust and the scarcity of information on diesel train EFs, we sought to measure these air quality effects by answering the following questions:

1. What are the DPM emission factors for locomotives in Washington State and how do these compare with published values?
2. Do open-top coal-carrying trains emit respirable coal dust ($PM_{2.5}$) into the air? If so, can we quantify the emissions?

To address these questions we measured PM_1, $PM_{2.5}$, CO_2, black carbon and meteorology at a location in the Columbia River Gorge next to the rail line. Because we wanted to quantify DPM and coal dust exposure and quantify the EFs from each train, we collected measurements every 10 s in order to identify the air quality impacts of individual trains. In a previous study, we measured a similar suite of parameters in 2013 at a site in Seattle, Washington, and (very briefly) at a site in the Columbia River Gorge (Jaffe et al., 2014). In the previous study, we quantified DPM emission factors from diesel trains, evaluated the neighborhood scale exposure to $PM_{2.5}$ from trains and found evidence that suggested emissions of coal dust, based on particle size. In the present analysis, we report new data taken in 2014 that more clearly identifies and quantifies the emissions of DPM and coal dust from coal-carrying trains.

2. Experimental

Measurements were made at a site between the towns of Lyle and Dallesport, Washington, in the Columbia River Gorge (approximately 45.7°N, 121.2°W) between June 7–August 10, 2014. The instruments were housed in a weather-proof enclosure, located about 10 m above and 20 m northeast of the rail line. Two video cameras were used; one took video of the trains at a 90° angle to the rail line, and one viewed the trains arriving/departing to the northwest. The rail line travels along the north side of the Columbia River. There were no roads between our site and the river. Our measurement site was approximately 200 m southwest of Washington Route 14, a state highway with light traffic. The measurement location used in 2014 was in the same general location, but about 300 m away, from the site we used for our 2013 measurements (Jaffe et al., 2014). At this site the rail line is almost completely flat; there is a maximum grade of 1 m per km in the next few km in either direction.

We used a DustTrak DRX Aerosol Monitor (Model #8533, TSI, Inc., Shoreview, MN) to measure size-segregated PM. The DustTrak reports 4 size fractions of PM mass concentrations: PM_1, $PM_{2.5}$, PM_{10} and TSP. The instrument uses aerosol scattering to calculate its measurements. Therefore, its measurements are not the same as mass-based measurements (Wang et al., 2009). The DustTrak is calibrated against Arizona road dust (ISO 12103-1) by the manufacturer and so will not correctly reflect the mass concentration for other types of aerosol. This is specifically the case for diesel PM because of the particle size (Park et al., 2011). Obtaining accurate measurements with the DustTrak requires comparing its measurements with a mass-based measurement (Moosmuller et al., 2001). The DustTrak has been used to quickly measure several PM size fractions and determine EFs of individual vehicles in several previous studies (e.g., Park et al., 2011; Dallmann et al., 2012), but usually after using a mass-based method to calibrate the response factor (Jamriska et al., 2004; Zhu et al., 2005; Cheng et al., 2006; Jaffe et al 2014). In our study, the DustTrak was

calibrated against two mass-based measurements—a Tapered Element Oscillating Microbalance (TEOM) and the EPA Federal Reference Method at a routine air quality monitoring station in Seattle, Washington (details below).

The DustTrak inlet was stainless steel tubing (4.8 mm i.d.) facing downward from a height of approximately 2 m above ground level. The flow rate through the inlet was 3.0 L per minute. With these conditions, the flow was laminar. To estimate the particle sampling efficiency, we used the methodology and program provided by von der Weiden et al. (2009). The wind speeds during train sampling in the CRG varied between 1 and 11 m per second (mps), with an average of 4.5 mps during the sampling period. For particles less than 2.5 μm aerodynamic diameter, we calculated greater than 90% particle transmissions at all wind speeds up to 15 mps. For particles between 3 and 10 μm aerodynamic diameter, the inlet sampling efficiency would be much less than 1.0 and vary with wind speed (von der Weiden et al., 2009). For this reason, we used only the $PM_{2.5}$ and PM_1 data in this analysis.

We measured CO_2 using a Licor-820 (Licor, Inc., Lincoln, NE) with a small vacuum pump for sampling. The inlet was a 4.8 mm i.d. stainless steel tube (38 mm long) connected to PFA tubing. We zeroed the instrument using CO_2-free air and calibrated it with a 395 ppmv standard from Airgas, Inc. We calibrated the instrument both before and after the deployment; the instrument response varied by less than 1 ppmv between these calibrations. We used DAQFactory on a PC to record data from the DustTrak, the Licor-820 (CO_2, cell temperature and pressure) and the meteorological station. We recorded 10-s averages for PM and CO_2 data.

To identify trains and quantify their speeds, we used two Night Owl cameras (Model CAM-MZ420-425M) that were equipped with infrared (IR) night vision. The cameras were motion activated and operated with iSpy open source camera security software. However, even with the IR capability of the cameras, we were unable to identify the type of trains at night. We considered using an auxiliary light to view the trains at night; however, this was rejected as the Columbia River Gorge is classified as a National Scenic Area, which limits lighting options. Only trains that could positively be identified as freight or coal were used in this analysis, so this excluded all trains passing our site in full darkness.

BC was measured using an aethalometer (Magee Scientific model AE22). BC data were collected at one-minute time resolution at 370 nm and 880 nm. BC loading was determined using infrared attenuation data at 880 nm alone, because at 370 nm, other organic compounds may contribute interference (Wang et al., 2011). The aethalometer determines raw BC concentration (BC_0, ng/m^3) from measured attenuation values (ATN, m^{-1}) via

$$BC_0 = 10^9 \times ATN/\sigma \quad (1)$$

where σ is the calibrated cross-section (16.6 m^2/g at 880 nm). As in our previous study (Jaffe et al., 2014), we applied a correction to the BC_0 concentrations to account for diminishing transmission as a function of BC loading. Transmission (Tr) is calculated from each attenuation value:

$$Tr = e^{-ATN/100} \quad (2)$$

Following Kirchstetter and Novakov (2007), we calculated the corrected BC mass loading (BC_{corr}, ng/m^3) as:

$$BC_{corr} = BC_0/(0.88 \times Tr + 0.12) \quad (3)$$

The DPM EFs are calculated for each passing train in units of DPM emitted per kg of diesel fuel burned using:

$$EF\,(PM_{2.5}) = \frac{\Delta PM_{2.5}}{\Delta CO_2} \times CF \times W_c \quad (4)$$

where the $\Delta PM_{2.5}/\Delta CO_2$ or "enhancement ratio" is calculated from the Reduced Major Axis (RMA) regression slopes of the 10-s CO_2 and $PM_{2.5}$ data for each passing train, in units of μg/m^3 per ppmv. CF is a conversion factor to convert CO_2 concentrations in ppm to μg C/m^3 units using the ideal gas law at 1 atm and 25 °C (1 ppmv CO_2 = 490.7 ugC/m^3). W_C is the mass fraction of carbon in diesel fuel (870 g C/kg fuel) (Lloyd's Register, 1995; Cooper, 2003), which yields overall units on the EF of g $PM_{2.5}$/kg fuel consumed. Yanowitz et al. (2000) showed that over 95% of diesel fuel carbon is released as CO_2.

Enhancement ratios ($\Delta PM_{2.5}/\Delta CO_2$ and $\Delta PM_1/\Delta PM_{2.5}$) were calculated from the 10-s data using the RMA regression method, which considers errors in both the x and y variables (Ayers, 2001; Cantrell, 2008). Absolute enhancements were calculated by subtracting out the PM, BC and CO_2 maximums during train passage from the background concentration measured prior to each trains passage. The RMA regression parameters were calculated for each train passage using a program written in Java utilizing Apache Commons Mathematics Library 3.3. The program first looked for a $PM_{2.5}$ enhancement of at least 3 μg/m^3 over the median value from the past 17 min (100, 10-s data points). The accuracy of the Java program to calculate PM and CO_2 enhancements and the RMA regression parameters were manually verified for approximately 20% of the peaks. All times in this manuscript are given in Pacific Daylight Time (PDT).

3. Results

3.1. Calibration of the DustTrak

We compared the DustTrak $PM_{2.5}$ concentrations with a TEOM and the filter-based Federal Reference Method (FRM) at a routine air quality monitoring site in Seattle, Washington (Beacon Hill), operated by the Puget Sound Clean Air Agency (PSCAA). Comparison data were obtained between April 30–May 20, 2014. TEOM data were continuous and reported on an hourly basis, the filter-based FRM measurements were for 24 h and conducted every third day only. At this site, the TEOM is a Thermo Fisher Scientific Model 1400AB with 8500C Filter Dynamic Measurement System (FDMS) with the Very Sharp Cut Cyclone (VSCC™) modification (U.S. EPA, 2014). This configuration is designated by the EPA as a Federally Equivalent Method (FEM) for $PM_{2.5}$. The inlet and flow configuration used for the DustTrak at the Beacon Hill site were identical to the configuration used in the Columbia River Gorge.

We found a very good correlations between the TEOM $PM_{2.5}$, the FRM and the DustTrak's reported $PM_{2.5}$. Table 1 shows the regression parameters.

The 95% confidence interval in the slope for the DustTrak-TEOM comparison is ±4.5%, whereas it is ±32% for the DustTrak-FRM comparison due to the very small sample size. In both cases, the intercepts are insignificantly different from zero (95% confidence interval overlaps zero). Because of this, we corrected all of the DustTrak PM data using the TEOM slope of 0.5577. This slope is 22% greater than the one reported by Jamriska et al. (2004), who reported a slope of 0.458. It also is approximately 14% greater than our earlier DustTrak comparison at a different site, where we reported a slope of 0.491 (Jaffe et al., 2014). These differences may be attributable to different aerosol types at these sites. Given these differences, we estimated the uncertainty in the corrected DustTrak PM_1 and $PM_{2.5}$ values to be ±20%.

Table 1
Regression parameters for the comparisons between the DustTrak data, the TEOM data and the FRM method at the PSCAA site at Beacon Hill, Seattle, Washington.

Comparison equation (using reduced major axis regression)	R^2	N
TEOM $PM_{2.5}$ (μg/m^3) = DustTrak × 0.5577 − 0.6977	0.74	485 (h averages)
FRM $PM_{2.5}$ = DustTrak × 0.5524 − 0.8433	0.92	7 (24-h samples)
FRM $PM_{2.5}$ = TEOM × 1.05 − 0.4326	0.96	7 (24-h samples)

3.2. Overview of observations on train emissions in the Columbia River Gorge

As each train passed our observation site, we may detect a peak in PM and CO_2, but this depended on the wind direction and wind speed. If the winds were from the north to northeast directions, our sensors recorded minor peaks only, or no peaks at all, in PM and CO_2. We found that small PM events had a lower correlation between the various parameters. For this reason, we screened out small peaks where the maximum $\Delta PM_{2.5}$ (enhancement above background) was <3 μg/m^3. If a peak larger than this value was detected and the video confirmed a simultaneous train passage, then we included this peak in our analysis. We included only freight and coal-carrying trains, since these were the dominant types that we observed in the Columbia River Gorge. Trains that carried mixed loads (e.g., freight plus coal), sand or other unidentifiable or uncovered cargo were not included in this analysis. We also observed very few passenger trains during the daytime hours, in contrast to our previous study in Seattle (Jaffe et al., 2014).

During this study, we observed 367 events with $\Delta PM_{2.5}$ >3 μg/m^3 that were identified by the video cameras as either freight or coal. We refer to each train passage with a detectable PM peak and verified by the video as a "train event." Table 2 shows a summary of the 367 train events, including number and average peak PM_1 and $PM_{2.5}$ enhancement values (over background). The peak PM_1 and $PM_{2.5}$ enhancements (10-s) from coal trains are about double the enhancements seen from freight trains. In addition, there are three extreme events with $PM_{2.5}$ enhancements greater than 75 μg/m^3 that were seen only for the coal trains. The differences between the peak PM enhancements for coal and freight trains are statistically significant ($P < .001$). The statistically significant difference remains even if these extreme events are excluded from the analysis. For all train events, there is an excellent relationship between the PM_1 and $PM_{2.5}$ data, although the fraction of $PM_1/PM_{2.5}$ varies by train type. This is discussed in Section 3.5 below.

However, only some train events showed a good correlation between $PM_{2.5}$ and CO_2. Fig. 1 shows an example of a freight train that passed our site on July 10, 2014. In this case, the $PM_{2.5}$ enhancement is 24 μg/m^3, the CO_2 enhancement is 39 ppmv and the two are very well correlated, indicating that the dominant source of PM is diesel exhaust. Fig. 2 shows an example of a coal-carrying train that passed by on July 18, 2014. For this example, the peak $PM_{2.5}$ concentration is more than 6 times the peak shown

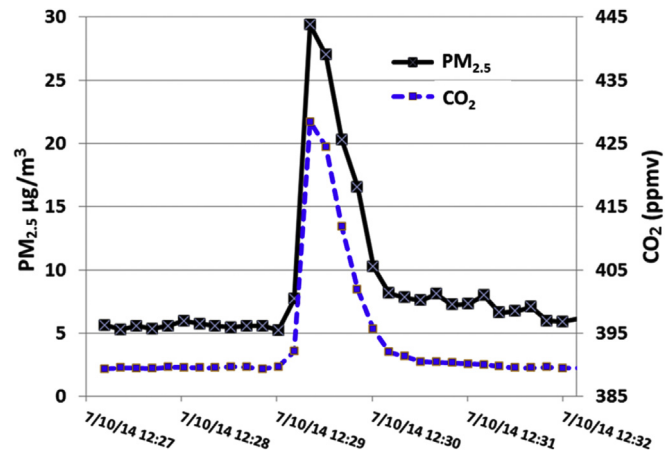

Fig. 1. $PM_{2.5}$ and CO_2 during passage of a freight train on 7/10/2014 at 12:29 PDT. The two values show a good correlation with an R^2 of 0.98 and a slope of 0.61 μg/m^3 per ppmv.

previously for the freight train, while the CO_2 enhancement is much smaller. In addition, the CO_2 peaks occurred at the start and end of the train passage due to locomotives at the beginning and end of this train, which is typical of the very long coal trains. The height of the CO_2 peak shows no obvious relationship with train type and likely varies mainly with meteorology, which influences the degree to which the combustion exhaust gases reach the measurement site. For the coal train (Fig. 2), the dominant source of PM is not diesel exhaust but coal dust. This was confirmed by the video (discussed below). It should be noted that DPM was probably present but is not apparent in the data due to the much larger coal dust peak. In this case, because the PM concentrations were not correlated to CO_2, we were not able to calculate a DPM emission factor. For this reason, we did not include train events in the DPM EF calculation if the $PM_{2.5}$–CO_2 R^2 is less than 0.5. We also excluded train events that had very small CO_2 enhancements (ΔCO_2 <2 ppmv), as these had erratic behavior.

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.apr.2015.04.004

3.3. DPM emission factors

The $\Delta PM_{2.5}/\Delta CO_2$ was used to derive the DPM emission factors. The average $\Delta PM_{2.5}/\Delta CO_2$ slope for all train events was found to be 6.56 μg/m^3 per ppmv, but this included many trains with a very poor correlation between $PM_{2.5}$ and CO_2. For the DPM emission factor calculation, we restricted our analysis to only those cases with an R^2 for the $PM_{2.5} - CO_2$ relationship of 0.5 or greater and a CO_2 enhancement of at least 2 ppmv. Table 2 shows the number of each train type that was used for the DPM analysis and statistics on the $PM_{2.5} - CO_2$ slope.

Table 2
PM and CO_2 data for freight and coal trains. Slopes for $\Delta PM_{2.5}/\Delta CO_2$ relationship is reported only for those train events with R^2 >0.5 and ΔCO_2 >2 ppmv.[a]

	Freight	Coal	All trains
Number	293	74	367
Average peak ΔPM_1 (μg/m^3)	11.0	19.7	12.5
Average peak $\Delta PM_{2.5}$ (μg/m^3)	10.7	20.9	13.0
Maximum $\Delta PM_{2.5}$ (μg/m^3)	57.2	232.3	232.3
Number with $PM_{2.5} - CO_2$ R^2 > 0.5 and ΔCO_2 > 2 ppm	152 (52%)	11 (15%)	163 (44%)
Mean/median $\Delta PM_{2.5}/\Delta CO_2$ slope (μg/m^3/ppmv)	0.70/0.56	0.71/0.56	0.70/.56
Max/Min slope	3.88/0.10	1.64/0.20	3.88/0.10

[a] In addition to the criteria given in the text above, we excluded one additional case with visible coal dust and an extremely high $PM_{2.5}$–CO_2 slope (12.0).

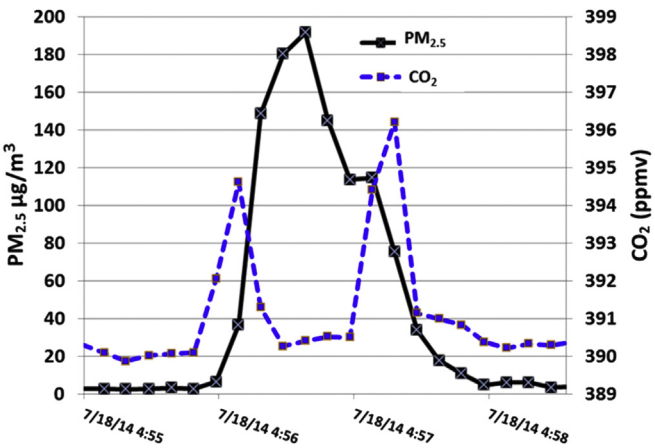

Fig. 2. $PM_{2.5}$ and CO_2 during passage of a coal train on 7/18/2014 at 4:56 PDT. The two parameters show no correlation during this time period. The train was observed to have locomotives in the front and rear, giving rise to the CO_2 peaks at the beginning and end of this time period.

The data in Table 2 show that while most freight trains were included in this analysis, the majority of coal trains were not included. This is due to the fact that most of the coal train events show a poor correlation between $PM_{2.5}$ and CO_2 (see Fig. 2). One coal train that would otherwise have been included in the DPM calculation had a $PM_{2.5} - CO_2$ slope of 12.0, more than 10× the mean value, and had visible coal dust in the video. Thus the large amount of $PM_{2.5}$ in this case cannot be attributed solely to DPM. This train event was not included in the DPM analysis. With this exclusion, the mean and median slopes for freight and coal trains are rather similar. Using equation (4), we find that the mean and median DPM EFs from our study are 1.2 and 0.99 g/kg fuel consumed, with an overall uncertainty of 20%. Our previous observations in the Pacific Northwest (Jaffe et al., 2014) found an average EF for diesel locomotives of 0.94 g/kg.

Diesel EFs for locomotives have been previously reported from several measurement campaigns. Kean et al. (2000) reported locomotive emission factors of between 1.8 and 2.1 g/kg using the EPA "NONROAD" model. A 2009 report (U.S. EPA, 2009) estimated that average locomotives EFs are declining about 5% per year, with a 2014 value of 0.98 g/kg. A study by Sierra Research in 2004 (Sierra Research, 2004) forecast a much slower decrease in the EFs of diesel locomotives, compared to U.S. EPA (2009), and for 2014 projected 1.4 g/kg. Our average measured EF is consistent with those cited in the above literature for the 2014 time frame, within the respective uncertainties.

3.4. Black carbon

We obtained simultaneous BC and $PM_{2.5}$ data on 294 of the trains. Table 3 reports the observed $BC/PM_{2.5}$ and $PM_1/PM_{2.5}$ enhancement ratios (discussed in Section 3.5).

These data show that, on average, 43% of the $PM_{2.5}$ was BC for all trains. In our previous study using similar data from 2013 (Jaffe et al., 2014), we found that the BC/PM_1 fraction was 52%, with most of those observations on freight trains. Our new data in 2014 indicates a significant difference ($P < .001$) in the average $BC/PM_{2.5}$ fraction for freight (0.47) and coal trains (0.29). Previous studies have found values that are similar to our freight train values for the BC/PM fraction. A study by Hildemann et al. (1991) found that 55% of diesel emissions were BC, and Watson et al. (1994) reported 45%. An Atlanta study (Galvis et al., 2013) found that diesel trains had BC to $PM_{2.5}$ ratios of 47–52%. The significant difference in the $BC/PM_{2.5}$ between coal and freight trains, shown in Table 3, indicates a significant coal dust component in the PM from the coal trains.

Table 3
$BC/PM_{2.5}$ and $PM_1/PM_{2.5}$ enhancement ratios for freight and coal trains.

	Freight	Coal	All trains
N (for $BC/PM_{2.5}$ analysis)	233	61	294
Mean/median $BC/PM_{2.5}$ (unitless)	0.47/0.40	0.29/0.20	0.43/0.35/0.27
Standard deviation on $BC/PM_{2.5}$	0.27	0.23	0.27
N (for $PM_1/PM_{2.5}$ analysis)	293	74	367
Mean/median $PM_1/PM_{2.5}$ (unitless)	0.93/0.93	0.96/0.96	0.96/0.96
Standard deviation on $PM_1/PM_{2.5}$	0.03	0.03	0.03

We assume that the coal dust has the same composition as the coal being shipped. This coal, from the Powder River Basin of Wyoming and Montana, has a relatively low carbon content compared to other coal types (ca 50% C), with the remainder of the mass made up of moisture and minerals, such as silicates, iron oxides and calcium oxide (NETL, 2012). While the low carbon content is partly responsible for the low $BC/PM_{2.5}$ fraction, shown in Table 3, our data suggest that other factors may also be involved. This could include a change in the mass absorption cross section for coal dust, as compared to diesel exhaust, which might reflect the impact of the coal mineral content, the organic matter composition or the size distribution of the particles.

3.5. $PM_1/PM_{2.5}$ fraction

The DustTrak calculates concentrations of PM in four size ranges, but due to the inlet sampling efficiency (discussed in Section 2) we considered only data for PM_1 and $PM_{2.5}$. Table 3 gives the statistical parameters on the $PM_1/PM_{2.5}$ enhancement ratio. Coal trains showed a larger mass fraction of particles above 1 µm aerodynamic diameter, and this difference is statistically significant. This reflects the significant contribution of coal dust to the $PM_{2.5}$ concentrations during the passage of the coal trains.

3.6. Influence of coal dust on $PM_{2.5}$ concentrations

In four cases, the videos revealed visible coal dust from the open-top coal trains. These visible coal dust plumes were seen in the four train events with the highest peak $PM_{2.5}$ concentrations (Table 4). We call these four train events with the highest $PM_{2.5}$ and visible coal dust "super-dusters." Two of the "super-duster" videos have been archived as part of the supplemental materials for this paper (8/7/2014 and 7/27/2014). Fig. 3 shows still images obtained from the video before and after train passage for the "super duster" on 8/7/2014, along with the measured $PM_{2.5}$ concentrations. We found that 4 out of 74 coal trains, or 5.4%, were classified as "super dusters" during our study.

A number of factors could be important in explaining the coal dust emissions of $PM_{2.5}$ from coal trains. These include quality of the surfactant application or factors that may disturb the coal/surfactant surface, such as high train speeds, exposure to high winds or rough handling during transport. While we have no information on

Table 4
The four train events with the highest peak $PM_{2.5}$ concentrations. In each case, a coal train with a visible coal dust plume was confirmed in the video recording.

Date/time (PDT)	Peak $PM_{2.5}$ conc. µg/m^3	Peak BC µg/m^3	$BC/PM_{2.5}$ ratio
8/7/14 17:28	232.3	53.5	0.23
7/18/14 4:57	188.8	88.9	0.47
7/20/14 14:07	77.6	8.86	0.11
7/27/14 21:16	53.1	9.13	0.17

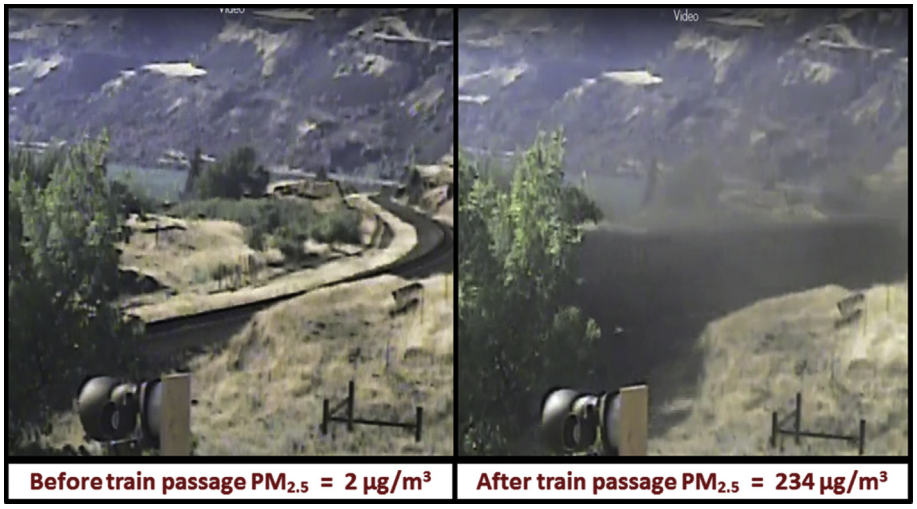

Fig. 3. Images captured from the video camera before and after coal train passage on 8/7/2014 at 17:28 PDT. The full video of this train passage is archived as part of the supplemental materials for this paper. The camera looks to the west, downriver in the Columbia River Gorge. The coal train is visible in the right image and was moving from left to right.

upstream conditions, our data do allow us to examine the influence that train and local wind speed may have played on dust emissions. To do this, we calculated train speeds for each coal train from the videos. We also calculated the vector component of the winds in the direction opposite to the trains' travel. The sum of train speed plus vector wind speed represents the true wind speed across the open-top coal trains. We refer to this as the effective wind speed. During our study, the average train speed was 71.3 km/h and the average vector wind speed was 14.9 km/h.

Fig. 4 shows the effective wind speed versus peak $PM_{2.5}$ for each coal train event. The four "super dusters" are shown as large red squares. While no simple relationship emerges from this analysis, the data do suggest that "super dusters" are more likely to occur when the effective wind speed is greater than 80–90 km/h. Above 90 km/h, the fraction of "super dusters" is 10.3% (3 out of 29 trains), compared to 5.4% at all wind speeds. Thus we can view wind speed as one factor that increases the risk of high-level coal dust exposure. However, the fact that many coal trains with effective wind speeds greater than 90 km/h are not "super dusters" indicates that other factors, such as quality of the surfactant applied to the coal surface, must also be important.

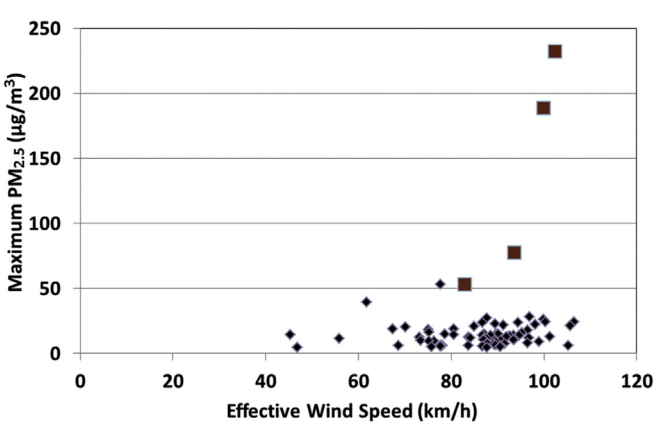

Fig. 4. Peak $PM_{2.5}$ enhancement for each coal train passage versus effective wind speed over the top of the train. The effective wind speed is calculated as the train speed plus the vector component of the wind at 180° to the train's movement. The four "super dusters" are shown as large red squares.

4. Conclusions

We measured PM_1, $PM_{2.5}$, BC and CO_2 during 367 train passages (train events) in the Columbia River Gorge. From the data, we calculated a DPM EF average of 1.2 g/kg fuel consumed (±20%) on 163 of those train events that show a good correlation between $PM_{2.5}$ and CO_2 (mostly freight trains). Our data indicate that nearly all open-top coal trains release coal dust, which contributes to enhanced $PM_{2.5}$ in the Columbia River Gorge. In four train events, that we call "super-dusters," the coal dust emissions led to visible dust plumes and the highest $PM_{2.5}$ concentrations observed in our study. But nearly all coal trains generate some degree of coal dust ($PM_{2.5}$) based on the following evidence:

1. Statistically higher peak $PM_{2.5}$ concentrations during passage of coal trains compared to freight trains. The peak $PM_{2.5}$ enhancements during a coal train passage are nearly double, on average, compared to the value during a freight train passage (Table 2);
2. The fact that most freight trains (52%) show a good correlation between $PM_{2.5}$ and CO_2, whereas very few coal trains (15%) show this relationship (Table 2);
3. The BC/$PM_{2.5}$ enhancement ratio is statistically higher for freight trains compared to coal trains (Table 3);
4. The PM_1/$PM_{2.5}$ enhancement ratio is statistically higher during passage of freight trains compared to coal trains (Table 3).

These four results demonstrate statistically significant differences between freight and coal trains, even if the four super-dusters are excluded from the statistical analysis.

Because our focus was on air quality, we measured the respirable size fractions of PM. Thus it is not possible to relate our observations to any data on bulk loss of coal during transport, since most of this loss will occur as much larger size particles. Because most coal train events show a poor correlation between $PM_{2.5}$ and CO_2, it is not possible to rigorously derive a fuel-based emission factor for the coal dust. Nonetheless, our data provide some guidance to anyone wishing to calculate total $PM_{2.5}$ emissions from the railway sector. Since the peak $PM_{2.5}$ values for coal trains are nearly double those for freight trains, it is reasonable to conclude that the total $PM_{2.5}$ emissions from coal trains are approximately double

those of freight trains. This would imply that the coal train $PM_{2.5}$ emissions consist of approximately half DPM and half coal dust.

Though all coal trains appear to generate some degree of dust, the "super-dusters" generate visible plumes and the highest concentrations of $PM_{2.5}$. "Super-dusters" represent 5.4% of all coal trains but 10.3% when the effective wind speed is greater than 90 km/h. This indicates that wind is one factor contributing to the coal dust emissions, but it is not the only explanatory factor.

Conflict of interest

The authors have no conflicts of interest to report.

Acknowledgments

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HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation,

Plaintiffs,

v.

BNSF RAILWAY COMPANY, a Delaware corporation,

Defendants.

CIVIL No. 2:13-cv-00967-JCC

DECLARATION OF MATTHEW RYAN IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

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I, Matthew Ryan, hereby declare:

1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action.
2. I reside at 9372 Cook-Underwood Road, Underwood, Washington, 98651, and have lived there for 21 years.
3. I am a member of Friends of the Columbia Gorge and of Columbia Riverkeeper because those organizations share my interest in protecting and restoring the natural and scenic values of the Columbia River and surrounding Columbia Gorge area. Friends of the Columbia Gorge (Friends) was initially founded to protect the Columbia River Gorge as a national scenic area, and now works to protect and preserve it. Friends accomplishes its mission through education and advocacy efforts, which include a focus on the quality of the Columbia River and its tributaries. Columbia Riverkeeper was founded to focus on the entire Columbia River, both upriver and downriver, and actively seeks to engage citizens in its conservation and environmental protection efforts. I support these groups because of their efforts to protect the Gorge waterways and scenic areas I love so much.
4. I understand that Friends of the Columbia Gorge, Columbia Riverkeeper, and other parties have filed a civil action asserting that Burlington Northern Santa Fe (BNSF) has discharged and is discharging coal and/or petroleum coke (petcoke) and their byproducts into Washington waterways without a permit.
5. I make this declaration in support of that action because it furthers my personal interests in the health and quality of the Columbia River, its tributaries, the Columbia River Gorge, and the communities and wildlife that depend on clean water in Washington state.

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6. I believe that coal and petcoke contamination from BNSF coal trains threatens the health of the Columbia Gorge and other waterbodies in which it is deposited. I know that coal contains some toxic chemicals, and it should not be allowed to fly out of the train cars into the Columbia River and other waterways. One of the reasons that I have lived in the Columbia River Gorge area for so many years is that it is a great place for outdoor recreation. But the continued discharges of coal and petcoke pollution significantly affects my ability, and that of my friends and family, to engage in recreational activities outdoors without fear of exposure to coal toxins. BNSF's coal pollution is negatively impacting my quality of life.

7. My concerns stem, in part, from my recreational interests in Columbia Gorge-area waterbodies, including the Columbia River, White Salmon River, Little White Salmon River/Drano Lake, Wind River, Spring Creek and the "Hatch," and the Klickitat River.

8. I enjoy canoeing, kayaking and paddleboarding, and engage in each of these activities four to five times per year (seasonally). I have a woodstrip canoe that I like to take out on the Columbia River, and I paddleboard there as well. I like to kayak on the Klickitat and White Salmon Rivers.

9. I also like to hike and ride my bicycle along roads and paths that follow Gorge waterways. I hike a couple of times per month. Falls Creek, a tributary of the Wind River, is one of my favorite hikes, and I hike there often. I ride my bicycle almost daily on roads that follow the White Salmon or the Klickitat, and I often see BNSF's coal train as I ride along Highway 14, which is right next to the Columbia River.

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10. My favorite recreational activities are kiteboarding and windsurfing, and the Columbia River Gorge is filled with great places to board and surf. This July, I was out windsurfing or kiteboarding twenty-eight out of thirty-one days, and over the course of a year, I probably windsurf and kiteboard between seventy-five and one hundred times. Some of my favorite spots are the "Hatch," next to its namesake Spring Creek Fish Hatchery, Swell City, Cheap Beach, and Doug's Beach. The mouth of the Klickitat River and mouth of the White Salmon River are also great places to windsurf and kiteboard.

11. I am growing increasingly concerned with the coal and petcoke contamination in Gorge waterbodies and my exposure to this pollution when I recreate in and around those waterbodies. I worry for my own health, the health of the fish and wildlife that depend on these waters, and the health of my fellow windsurfers, kiteboarders, and other Gorge recreationists. I am concerned about the general degradation of the waterways and the impact that pollution has on the quality of life of residents in the area.

12. I have frequently seen thousands of little BB-like pieces of coal within a couple hundred yard stretch in depressions between the gravel and the white fog line on the west side of the White Salmon near Highway 14. The coal bits appear to have been polished from tumbling around with the rocks. I have found coin-sized chunks of coal and small pellet-like pieces of coal on the railroad causeway on the south side of Drano Lake. I have also personally been pelted with coal chunks flying off of a passing coal train as I stood near my vehicle on Highway 14. Given the number of the BB- and pellet-size pieces that I have seen on the road, and the size and speed at which the coal chunks exit the train cars, I am very concerned that similar coal and petcoke chunks are being deposited directly

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into the Gorge waters as the coal trains pass over bridges and causeways through the Gorge.

13. My enjoyment of the recreational activities described above has been negatively impacted by my knowledge of the presence of coal and petcoke pollution, and if this pollution continues to degrade Gorge waters, my enjoyment will be further diminished. I hope that this lawsuit is successful in eliminating and cleaning up the coal pollution; otherwise, I may have to curtail or relocate the recreational activities that I enjoy so much and would like to continue.

14. If BNSF is required to cease contaminating Columbia Gorge waterways with the coal and petcoke pollution, then scenic, natural, and recreational values of the Columbia River Gorge area will be protected, in accordance with my personal interests and that of Friends of the Columbia Gorge and Columbia Riverkeeper. The Columbia Gorge ecosystem, including especially aquatic life, will become healthier, communities along the Gorge will be healthier, and outdoor enthusiasts like me will be able to fully enjoy our recreational pursuits.

15. In my personal opinion, coal and petcoke do not belong in the Gorge. They are not naturally occurring here. BNSF railroad and various coal companies are adding to their prior contamination of our waterways by transporting more coal, petcoke and related pollutants. The coal and petcoke pollution from the BNSF trains must not be allowed to continue.

16. If BNSF were required to cease its pollution of Columbia Gorge waters, my concerns about the negative effects of coal and petcoke pollution in Gorge waters would be

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lessened, and I would be able to enjoy the recreational activities described above without fear of exposure to toxic contaminants from BNSF trains.

I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Underwood, Washington this 30th day of August, 2013.

Matthew Ryan

8.30.13

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CERTIFICATE OF SERVICE

I hereby certify that on September 3, 2013, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system, which will automatically send notification of such filing to the following:

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HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation,

Plaintiffs,

v.

BNSF RAILWAY COMPANY, a Delaware corporation,

Defendants.

CIVIL No. 2:13-cv-00967-JCC

DECLARATION OF JEREMY BECHTEL IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

I, Jeremy Bechtel, hereby declare:

1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action.
2. I live at 2001 Salmon Falls Road, Washougal, Washington, 98671, and have lived there for about ten years.
3. I work as a sales representative for a beverage distributor based in Vancouver, Washington. My sales territory includes the Columbia River Gorge, so I travel daily on

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highways in the Gorge. I drive on Highway 14 between Lyle and Vancouver at least once per week.

4. I understand that Friends of the Columbia Gorge and other parties have filed a civil action asserting that Burlington Northern Santa Fe (BNSF) has discharged and is discharging coal and/or petroleum coke (petcoke) and their byproducts into Washington waterways without a permit.

5. I have been a member of Friends of the Columbia Gorge on and off since approximately 2008. Friends of the Columbia Gorge represents the scenic, natural, and recreational interest I have in the Columbia River Gorge area. Friends of the Columbia Gorge is the only non-profit organization I am aware of that is dedicated entirely to protecting the Columbia River Gorge.

6. I first became aware, and subsequently very concerned, about coal and petcoke contamination of Columbia River Gorge waters after an incident last August in which my vehicle, along with several others, was pelted with coal chunks up to the size of baseballs flying off of a BNSF coal train as I drove west on Highway 14 alongside the Columbia River. The incident is described in greater detail in a statement that I prepared shortly after the incident. A true and correct copy of the statement that I prepared is attached to this declaration as Exhibit 1. I prepared the statement to record my recollections of what occurred. The incident is most frightening experience that I have had during all of my years driving on Highway 14. I was surprised and relieved that a multi-vehicle accident did not occur. After this event, I began to research the issue of coal spilling from BNSF's trains and learned more about the potential consequences of the coal pollution.

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7. I began learning about other instances of coal and petcoke deposits coming from BNSF coal trains, and started noticing coal chunks along the side of the road on Highway 14. I have seen some coal bits approximately the size of peas and pencil erasers. Once I became aware of these deposits, I started to notice them more and more, and have observed that the sides of the tracks appear to be getting darker because of the coal deposit buildup. Seeing all of the coal deposits alongside the tracks, so close to Gorge waters, makes me very concerned that the coal is polluting the Columbia River and other waterbodies in the Gorge area.

8. My concerns stem, in part, from my recreational interests in Columbia Gorge-area waterbodies, including the Columbia River, White Salmon River, Little White Salmon River, Klickitat River, and Wind River.

9. I love rafting on the Columbia Gorge waters, and raft about 5-6 times per year. Currently, I am preparing for a trip to raft the length of the White Salmon River coming up the second weekend in September. I also enjoy fishing in these waters, specifically the Wind River, and fish approximately 2-3 times per year, although when the Steelhead population was healthier, I fished more often. It is important to me that the waters where I fish and raft are free of pollution. Knowing that BNSF's coal and petcoke discharges are polluting Gorge waters causes me to enjoy these activities less. I intend to continue rafting and fishing, but would like to do so without concern of exposure to toxic coal pollutants.

10. I also really enjoy birdwatching, and especially like to watch the eagles at the Klickitat River on a sandspit. I am concerned about the fact that these birds are feeding in the water right underneath the train trestle, and worry about the effects that the coal

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contamination might have on them and on the osprey and other birds that nest or feed in that area. I want to continue to observe the birds and other species in the Columbia Gorge region, but would like to do so without worrying that they are exposed to or ingesting coal pollution.

11. I like to forage and berry-pick, and have found some great places in the Gorge area to forage for mushrooms. There is a creek just east of Stevenson, near the train tracks, that tends to be a good place to find chanterelles in the fall. I also like to forage for them along the Wind River. I enjoy picking berries, and just picked some huckleberries a few weeks ago. I forage about 15-20 times during a season, and berry-pick about 3 or 4 times per season. Since the mushrooms and berries that I gather will ultimately be eaten by me or my family and friends, it is important to me that they are sourced from clean, pollution-free areas. My knowledge of the presence of coal pollution in areas where I gather food gives me great concern. I would like to be able to engage in these activities without fear that I am exposing myself to coal contamination.

12. My enjoyment of the recreational activities I listed above is already diminished by my knowledge of the presence of coal, petcoke and related pollution in the Gorge waterways, and if this pollution continues to degrade Gorge waters, my enjoyment will be further diminished.

13. I am very interested in pursuing kiteboarding and stand-up paddling as recreational activities. These activities are popular recreational pastimes in the Columbia Gorge and appear to be very enjoyable. However, I am reluctant to engage in these activities because of my knowledge that the Columbia River and its tributaries are being polluted with coal and petcoke from BNSF coal trains. Since kiteboarding and stand-up paddling

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brings people into direct contact with the water, I am worried about the possible increased exposure to coal toxins. If I knew that BNSF was no longer discharging coal and petcoke into Gorge waters, I would engage in one or both of these activities.

14. If, as a result of this lawsuit, BNSF is required to cease contaminating Columbia Gorge waterways with the coal and petcoke pollution, then my recreational and scenic interests and the interests of Friends of the Columbia Gorge will be protected.

15. In addition to the concerns that I have over the current coal pollution to waters of the Columbia River Gorge as the trains pass through the region, I am also worried about the possibility of a train derailment. I have noticed the buildup of coal particles on the tracks and in the ballasts, and am concerned that if this buildup continues, it could eventually lead to a train derailment. A derailment in this area would be disastrous—it could cause serious injuries to people on or near the train, block access to emergency or other essential services and utilities, and dump massive quantities of coal and petcoke into nearby waters. With the possibility of increased coal train traffic, the buildup on the tracks will likely increase as well, making the threat of a derailment very real.

16. In my opinion, coal and petcoke do not belong in the waters of the Gorge. They are not naturally occurring here. I am very concerned about the effect that these pollutants have on the Columbia River, its tributaries, the species that depend on clean water, and the health and recreational interests of me and my family and friends. If BNSF were required to stop discharging coal pollutants into Columbia River Gorge waters, my concerns in these areas would lessen and I would be able to once again engage in the recreational activities described above with greater peace of mind and heightened enjoyment.

///

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I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Washougal, Wash. this 29th day of August, 2013.

Jeremy Bechtel

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CERTIFICATE OF SERVICE

I hereby certify that on September 3, 2013, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system, which will automatically send notification of such filing to the following:

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Sarah Matsumoto, *an employee of*
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Declaration of Jeremy Bechtel
Exhibit 1

August 22, 2012

Compiled by: Friends of the Columbia Gorge (FoCG)

As told by: Jeremy Bechtel, husband of a FoCG staff member (Full Disclosure)

[A COAL TRAIN INCIDENT ON WA HIGHWAY 14]

While driving in a line of traffic on WA Highway 14 in the Columbia Gorge, Jeremy Bechtel was pelted with chunks of coal and coal dust from a coal train traveling close to the highway. This almost resulted in a multi-car accident. Click on the aerial photo below to open a Google Map showing where this incident took place.

STATE OF WASHINGTON

COUNTY OF SKAMANIA

DECLARATION OF JEREMY BECHTEL

I, JEREMY BECHTEL, make this declaration based upon my personal knowledge and belief and declare as follows:

1. I am a resident of Skamania County, Washington.

2. I am currently a member and supporter of Friends of the Columbia Gorge. I support Friends of the Columbia Gorge because it advocates for my interest in protecting the scenic, natural, cultural, and recreational resources of the Columbia River Gorge and surrounding landscapes.

3. I live at 2001 Salmon Falls Road, Washougal, WA 98671 which is located approximately 20 miles west of where the coal train incident I describe below took place. I have lived at this address for 9.5 years.

4. I work as a sales representative for Stein Distributing, a distributor of beer, wine and natural beverages located in Vancouver, Washington. My job involves daily travel on highways in the Columbia Gorge.

5. In addition to driving through the Columbia Gorge for work, my family and I drive through the Columbia Gorge for daily household trips, such as shopping for groceries. We also recreate in the Gorge and use Highway 14 to access numerous recreation sites.

6. A large increase in the number of coal trains traveling along the Burlington Northern Santa Fe (BNSF) railroad, which closely parallels Washington State Highway 14 in the Columbia Gorge, would increase the likelihood of dangerous incidents resulting from coal dust

blow-offs, such as an incident I recently experienced that nearly resulted in a multi-vehicle accident, as described below.

7. I am regularly exposed to coal dust from trains on the BNSF railroad when I travel Highway 14 in the Columbia Gorge.

8. On August 22, 2012 at approximately 4:00 p.m., I was driving back from a sales call, headed west on Highway 14 near milepost 51 in a line of traffic. In front of me was a semi-truck followed by one car. Behind me was another car that was tailgating (following too close to) my vehicle. On the train tracks paralleling the highway, approximately 15 feet from our vehicles, a coal train was keeping pace with us as we traveled westward. The train suddenly rounded a sharp bend in the tracks, which exposed the railcars to a strong westerly wind (I estimate it at 30 mph). Coal from at least four of the railcars blew in a northeast direction off the top of the cars and bombarded the line of vehicles I was in. Coal chunks as big as baseballs collided with my vehicle's windshield, and it was only because the coal was soft and broke up upon impact that the coal did not puncture or break my windshield.. The coal chunks left tar marks on my vehicle.

9. The semi-truck, being the first vehicle in the line-up, was hit by the most coal dust and coal chunks. The semi-truck driver suddenly slammed on his brakes causing a chain reaction. The car ahead of me had to slam on its brakes to avoid an accident. In turn, I also had to brake, but I was concerned about being hit by the car tailgating me, so I steered to the right into the road gravel in order to create space for the car behind me to slow down. . I was very concerned about getting rear-ended by the car behind me, but fortunately the semi-truck passed through the worst of the coal bombardment and started accelerating again, which allowed all of us to put more space between our vehicles.

10. I was shaken by this incident and consider it the closest near-accident I have had in all my years of driving in the Columbia Gorge, including winter-time driving. For the sake of my family and my business driving, I do not want to see an increase of coal trains traveling through the Columbia Gorge.

11. The cover page of this declaration shows photographs of the location of the August 22, 2012 coal train incident and an aerial photo from Google Maps identifying where this took place.

12. I declare under penalty of perjury that the foregoing is true and correct to the best of my personal knowledge, information, and belief.

Executed in Washougal, Washington this 31st day of October, 2012.

Jeremy Bechtel

HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation, Plaintiffs, v. BNSF RAILWAY COMPANY, a Delaware corporation, Defendants.	CIVIL No. 2:13-cv-00967-JCC DECLARATION OF DAVID BERGER IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

I, David Berger, hereby declare:

1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action. I am aware that Columbia

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Riverkeeper and other parties have filed a civil action asserting that Burlington Northern Santa Fe (BNSF) has discharged and is discharging coal, coal dust and/or petroleum coke (petcoke) and their byproducts into Washington waters without a permit in violation of the Clean Water Act. Columbia Riverkeeper represents my interests in this lawsuit.

2. I make this declaration in support of this litigation because I believe it is necessary to protect the water quality of the Columbia River watershed, where I live and recreate. I also believe this litigation is necessary to protect the safety of my small community from the danger associated with coal and coal dust being deposited into the water and on the railroad tracks.

3. I reside at 728 7th Street, Lyle, Washington 98635. Lyle is a small town located in Klickitat County, along the shore of the Columbia River in Washington state. I have lived in Lyle for approximately eight years.

4. Prior to residing in Lyle, I received my Bachelor's of Science degree in mechanical engineering. I also obtained a Master's Degree in environmental engineering in water, wastewater treatment and water quality modeling from Manhattan College in New York City in 1974. After receiving my Master's, I worked for the Environmental Protection Agency in both New York City and Portland, Oregon. At EPA, my work duties included administering grants for sewage treatment facilities, and inspecting industries for compliance with air quality and hazardous waste regulations. Between the two EPA jobs, I worked for Hydroscience Inc., a private consulting company, as a water quality computer modeling engineer. I have also worked for Oregon Department of Environmental Quality where my work duties included reviewing permits and inspecting industries for compliance with water and air quality regulations. I also served as a

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contractor for the City of Portland on special industrial waste treatment projects, and an air quality study. In 1980, I created a part of a civil/mechanical engineering program at Portland Community College teaching classes to engineering students on water, air, hazardous waste and ground water pollution control. I taught these classes and other engineering math, and chemistry classes for approximately 24 years and then moved to Lyle, Washington, where I now consider myself to be retired.

5. I am an active member and supporter of Columbia Riverkeeper, and I have been an active volunteer with Columbia Riverkeeper for the last eight years. Columbia Riverkeeper is a non-profit organization that works to protect the Columbia River watershed. I enjoy working with and contributing to Columbia Riverkeeper because they do a lot of the water quality monitoring work that government agencies like Oregon Department of Environmental Quality used to do. As an environmental engineer, I believe that water quality monitoring is an important part of protecting and restoring the Columbia River.

6. I submit an annual donation to support the work of Columbia Riverkeeper and have volunteered as a water quality sampler for the previous seven years. I have not been able to do any water quality monitoring this year. As volunteers, we took water samples at Doug's Beach on the Columbia River and an unnamed public park on the Klickitat River, about one mile above the confluence with the Columbia River. We sampled and recorded data for dissolved oxygen, pH, turbidity, temperature, and conductivity. Columbia Riverkeeper routinely monitors the quality of the waterways in the Columbia River watershed as part of its advocacy and education work.

7. I have also been engaged in other activities on behalf of Columbia Riverkeeper. As a volunteer, I have collected names and contact information of individuals interested in

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supporting the organization, and have attended public meetings as a member of Columbia Riverkeeper, and on my own behalf on environmental issues related to the water quality of the Columbia River, including but not limited to wetland protection, a coal burning power plant, coal transport, Hanford Nuclear Reservation, and land use. On my own behalf, I have written letters to the editors of newspapers about coal and its impact on the environment.

8. In addition to being a member of Columbia Riverkeeper, I am also a member of Friends of Columbia Gorge, a former Board member for the Klickitat Trail Conservancy and a former Board member of the Oregon Conservancy Foundation.

9. I believe that the burning and transportation of coal is one of the most significant problems that the Columbia River faces today. I am concerned about the presence of coal, coal dust and petcoke in the Columbia River and the waters that feed the Columbia River because I believe the presence of coal in the water pollutes the water and creates a threat to public safety because of the heavy metals contained in the coal. In addition, the ultimate burning of the coal emits mercury into the atmosphere, which studies have shown can end up in the Columbia River Basin, regardless of where the coal is ultimately burned.

10. I believe that the transportation of coal in the uncovered coal cars used by BNSF constitutes a threat to the public safety of the community of Lyle. Lyle is a small town, with only a volunteer fire department. It is my understanding that the deposition of coal and coal dust on the tracks that spill out of the rail cars can lead to more frequent train derailments, accidents, and fires. The small community of Lyle would be ill equipped to

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deal with the aftermath of any kind of coal-related derailment, whether on the land or in the waterways.

11. I live and own my own home approximately one mile away from the Columbia River. I see the Columbia River everyday, regularly observe and photograph the wildlife that reside and depend upon the Columbia River, regularly swim in the River during the summer months, and whitewater and flat water kayak in the Columbia River and its tributaries.

12. I am aware that there are plans to build more coal transport terminals in Washington, which increases the likelihood that additional coal-carrying trains will travel over and adjacent to the Columbia River, depositing more coal and coal dust into the watershed. For me, this will diminish the aesthetic value of living in Lyle. I also think this could indirectly affect the economic value of my own property. Lyle is such a small community that, even though the train does not pass adjacent to my property and thus does not spill chunks of coal onto my property to my knowledge, the economic impact on other properties that are alongside the rails would necessarily affect the value of my own property.

13. My recreational interests and activities revolve around a number of rivers and lakes in the Columbia River watershed that I have visited frequently, and that I intend to visit again on at least an annual basis. In terms of the transportation of coal on railways by BNSF, I am particularly concerned about the Columbia River, Klickitat River, White Salmon River, Rowland Lake, Spearfish Lake, Horsethief Lake, and Major Creek. Many of the foregoing waterways that I visit and use are impacted by coal and coal dust pollution

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from the BNSF coal trains because the coal trains pass adjacent and/or directly over them.

14. I regularly engage in open-water swimming, whitewater and flat water kayaking, hiking, bird watching, nature study, photography, cycling, and picnicking on or along the banks of the water bodies listed above. The presence of coal in the water detracts from my enjoyment of all of these activities in that it will impact the food chain, have deleterious affects on wildlife, harm visibility, and damage water quality.

15. As an open-water swimmer, I believe that the presence of coal in the water constitutes a threat to my health. The toxins that I am aware of in coal include heavy metals, which are known to be harmful in even small doses. Fortunately, when I am swimming, I only take in a small amount of water, but the levels of heavy metals in the water will only increase with more coal spilled into the waters in which I swim.

16. I am also concerned for others who engage in other forms of recreation, such as windsurfing, that requires the participants to take in much more water. While I do not personally eat fish caught from the Columbia River, I am concerned for the Tribal fishermen whose way of life depends upon fish caught and eaten from the waters of the Columbia River watershed. The Tribal fishermen serve a vital role in the local economy and coal in the water necessarily detracts from this historically and culturally significant part of the Columbia River economy.

17. Because I live so close to and recreate on the Columbia River, I also enjoy looking at the water. The Columbia River is a sight to behold. The presence of coal and coal dust in the water degrades this recreational experience and contributes to the water quality problems of the Columbia River.

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18. I have personally seen coal collected by staff or volunteers for Friends of the Gorge along the north side of the Columbia River, adjacent to the BNSF train tracks at Columbia Hills State Park. I believe that there is coal in the waters of the Columbia River that is not visible from the surface since the trains pass directly over and adjacent to the River in many places on the route from Eastern Washington to Portland, Oregon. In fact, the train passes directly over the water at one of my favorite swimming spots, Horsethief Lake. Horsethief Lake is adjacent to the Columbia River and is only separated from the River by the berm for the railroad tracks. Therefore, coal spilling into the river at this point directly affects my ability to swim at Horsethief Lake.

19. I believe that BNSF's deposition of coal, coal dust and petcoke into the Columbia River watershed has harmed me because coal in the water negatively affects my ability to engage in recreational activities that I enjoy and threatens the community in which I live. I believe that if the court were to issue a decision requiring BNSF to operate in a manner that ensures that no coal or coal dust is deposited into the Columbia River watershed, my interests in preserving my way of life and protecting the environment in my community would be protected.

I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Lyle, Washington, on August 30, 2013.

David Berger

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CERTIFICATE OF SERVICE

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s/ Sarah Matsumoto
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HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation,

Plaintiffs,

v.

BNSF RAILWAY COMPANY, a Delaware corporation.

Defendants.

CIVIL No. 2:13-cv-00967-JCC

DECLARATION OF PETER CORNELISON IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

I, Peter Cornelison, hereby declare:

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1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action.
2. My principal place of business is the office of Friends of the Columbia Gorge located at 205 Oak Street, #17, Hood River, OR 97031. I serve as Field Representative for the organization.
3. I understand that Friends of the Columbia Gorge and other parties have filed a civil action asserting that Burlington Northern Santa Fe (BNSF) has discharged and is discharging coal and/or petroleum coke (petcoke) and their byproducts into Washington waterways without a permit.
4. In light of my personal and professional concern about the health of the Columbia Gorge, I am please to offer my declaration.
5. Friends of Columbia Gorge was founded in 1980 to seek federal protection for the Columbia River Gorge as a national scenic area. Friends of the Columbia Gorge is the only non-profit organization dedicated entirely to protecting the Columbia River Gorge. I am a member of Friends of the Columbia Gorge, and have been since 2003. As well, I have served as the organization's field representative since 2003, in which capacity I am responsible for building support and activism among Gorge residents for protecting the Columbia Gorge.
6. I am also a Hood River resident and have been active in a number of local conservation causes.
7. Contamination of Washington waterways with coal and petcoke from BNSF threatens the health of the Columbia Gorge.

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8. I live and own property just a mile away from the Columbia River, travel by it everyday, and work in Friends' offices in the city of Hood River just five blocks from the confluence of the Hood and Columbia Rivers.

9. My concerns stem, in part, from my recreational interests in Columbia Gorge-area waterbodies, including the Columbia River, White Salmon River, Little White Salmon River, Wind River, Rock Creek and the Klickitat River. The BNSF rail road train tracks are very close proximity, either next to these rivers or the tracks cross over these rivers. In these rivers, on at least an annual basis, I engage in kayaking (about 5-7 times per year), windsurfing (about 3-4 times per year), rafting (2-3 times per year), swimming (5-6 times per year), fishing (3-4 times per year) and, at least weekly outside of winter months, engage in hiking, stream-walking, and photography. I know all of these rivers from at least one of these activities. For example, this month (August 2013) I rafted down the White Salmon River. I hope to continue these activities in these waterways, and expect within the next year also to take up kite-boarding and standup paddle boarding in the Columbia Gorge.

10. However, I am increasingly concerned about contact with water that is contaminated by coal and petcoke, and with the increasing degree to which the quality of the waterways is degraded by the coal and petcoke discharges from the trains. If the contamination of Columbia Gorge waterways by the coal and petcoke trains is not stopped by this civil action, then a central feature of our organization's mission and my personal and professional goal to protect the Gorge will be undermined. As well, I will face a continuing risk of damaged health if I continue to pursue water-contact activities in the face of mounting pollution from BSNF's offending trains. Accordingly, I anticipate that

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I will need to curtail or cease engaging in them, unless through this litigation the coal train contamination is halted and the coal in the rivers cleaned up. Right now, I try to avoid areas where I know that excessive coal is present.

11. My enjoyment of the recreational activities I listed above is already diminished by my knowledge of the presence of coal, petcoke and related pollution in the Gorge waterways, and if this pollution continues to degrade Gorge waters, my enjoyment will be further diminished.

12. On the other hand, if by this lawsuit BNSF is required to cease contaminating Columbia Gorge waterways with the coal and petcoke pollution, then the Gorge ecosystem, including especially aquatic life, will become healthier, communities along the Gorge will be healthier, the mission of Friends of the Columbia Gorge will be supported, and I and others concerned about the present pollution will be able to breathe easier while pursuing our profession and personal interests.

13. In key respects, my recreational interests intersect with and bolster my professional work. Some of the activities in which I regularly engage in the Gorge area aim to increase member and public commitment to protection of the Columbia Gorge. Accordingly, I help lead a number of hikes and picnics each year to introduce, share and reconnect members and supporters of Friends with the beauty and grandeur of the Columbia Gorge area. However, the increased contamination from BNSF's coal and petcoke trains is diminishing my enjoyment of and the beauty of these hikes and picnics. I would like to be able to lead members and supporters of Friends in these activities without fear of exposure to coal, petcoke and related pollution.

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14. In my professional opinion, coal and petcoke do not belong in the Gorge. They are not naturally occurring here. Accordingly, BNSF Railway Company is introducing a foreign substance by its injection of coal and petcoke into Gorge waterways. Coal, petcoke and related materials are pollutants, and such contaminated water may impose both physical and chemical harm to juvenile salmon, other fish, and other aquatic life. My concern in this regard was amplified by a recent article from Sightline Research Institute titled "How Coal Affects Water Quality: State of the Science." BNSF railroad and various coal companies are compounding their prior contamination of our waterways with more coal, petcoke and related pollutants.

15. I have personally observed how the coal, petcoke and related pollutants caused by the trains deposit large quantities of chunks and dust onto steep slopes immediately adjacent to and over these waterways. I have seen this at the confluences of the Columbia River and the White Salmon River, Little White Salmon River, Wind River and Rock Creek and an unnamed creek in Murdock, WA. I have also seen this by boat along a section of elevated railroad track at Horsethief Lake, WA.

16. Coal and petcoke are already polluting the Columbia Gorge and have accumulated to a depth of two to six inches at a number of places on land and at numerous places where the tracks are near water (although the dust is dispersed in water). This is from just one to four coal and petcoke trains per day. Present coal terminal proposals, if built, could lead to the increase of this train traffic up to 20 to 30 coal and petcoke trains per day.

17. The coal and petcoke pollution from the BNSF trains must not be allowed to continue and further pollute the unique geologic, cultural and scenic treasure that is the Columbia Gorge National Scenic Area.

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I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Hood River, Oregon this 2nd day of September, 2013.

Peter Cornelison

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CERTIFICATE OF SERVICE

I hereby certify that on September 3, 2013, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system, which will automatically send notification of such filing to the following:

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HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation, Plaintiffs, v. BNSF RAILWAY COMPANY, Defendant.	CIVIL No. 2:13-cv-00967-JCC DECLARATION OF MICHAEL LANG IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

I, Michael J. Lang hereby declare:

1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action.

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2. My principal place of business is the office of Friends of the Columbia Gorge located at 522 S.W. 5th Ave, #720, Portland, OR 97204. I serve as Conservation Director for the organization.
3. Friends of the Columbia Gorge and other parties have filed an action under the Clean Water Act against Burlington Northern Santa Fe (BNSF) for its unpermitted discharges of coal and petroleum coke (petcoke) and their byproducts into Washington waterways, including the Columbia River.
4. I make this declaration in support of that action.
5. Friends of Columbia Gorge was founded to protect the Columbia River Gorge as a national scenic area and now works to protect its natural and scenic values. We work to achieve our mission by educating the public about the outstanding resources of the Gorge and advocating for protection of those resources – including the quality of the Columbia River and its tributaries – by the enforcement of critical environmental laws.
6. I am a member of Friends of the Columbia Gorge.
7. I have served as the organization's Conservation Director since 1997, in which capacity I oversee all aspects of our monitoring and litigation program, policy development and advocacy, coalition building, public education and media work, and lobbying efforts.
8. I am personally and professionally concerned about coal contamination of Washington waterways stemming from BNSF coal trains.
9. The Columbia River Gorge was designated by Congress as a national scenic area in recognition of its natural beauty and environmental integrity. The large quantities of coal and petcoke discharged from BNSF trains undermine those values. Friends of the Columbia Gorge's primary mission is to protect the Gorge. Accordingly, it is imperative

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to my organization that BNSF be made to cease its discharges of coal and petcoke into Washington waterways.

10. My concern also stems from my personal activities in Columbia Gorge-area waterbodies. I am an avid recreational fisherman, and fish for steelhead and trout on the tributaries of the Columbia -- including in the Sandy River, Deschutes River and the Klickitat River. The BNSF coal and petcoke discharges threaten both the health of the species that I fish for and the health of people who consume these fish.

11. I also regularly hike – at least once per year – along many Washington tributaries that feed into the Columbia River, including Catherine Creek, Gibbons Creek, Duncan Creek, Woodard Creek, Hardy Creek, Hamilton Creek, Greenleaf Creek, the Little White Salmon River, the White Salmon River, the Wind River, and the Klickitat River. BNSF's trains cross these tributaries. As well, I hike along the Columbia River. When hiking, I engage in bird-watching, wildlife observation, plant identification and photography. Often these hikes include my family, and the outings often include picnics.

12. Through my work and in recreation I have occasion to travel along the Columbia River, often on its north side. I have frequently seen coal contamination from the BNSF. In particular, I have witnessed coal contamination at the mouth of the Little White Salmon River and on the banks of the Columbia River. I have also witnessed the coal contamination at Columbia Hills State Park along the banks of the Columbia River and within the river. The presence of coal and petcoke contamination of these banks means that coal and petcoke were and are directly discharged by BNSF into the Columbia River.

13. My concerns about this contamination are several. First, I am concerned about impacts to human health, since I and people in communities throughout the Columbia Gorge

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consume Columbia River fish and, because the contamination is cumulative, the fish increasingly are contaminated with coal and petcoke and their by-products discharged by the BNSF trains. Accordingly, I am concerned that these toxins will find their way into the bodies of persons living in communities up and down the Columbia, and in fact wherever the fish are consumed - including by my family and me.

14. Second, I am concerned about the health of the fish populations and other organisms that are confronted with degraded habitat, as their habitats are critical to their lifecycles. I am also concerned about other waterfowl and mammals that use the Columbia River and its tributaries, and so feed on the salmon, other fish, and other river organisms. These include Columbia River sturgeon, otter, beaver, bald eagle, osprey, cormorants and other birds of prey.

15. Third, I am concerned about the impact of the water quality degradation on the future of the Columbia Gorge region itself. In particular, I fear that the increasingly degraded water quality, and the widespread knowledge of that adverse development, will diminish the quality of life and quality of the experience for those living or visiting the Gorge. My enjoyment of the Gorge, for instance, is impaired by my understanding that Gorge waterbodies are under nearly constant assault by the BNSF coal and petcoke trains.

16. I believe that our action to enforce the CWA, if successful, will stem that degradation and remediate at least some of the damage.

17. The Columbia Gorge itself, and the Friends of the Columbia Gorge as an organization, face enough challenges even in the absence of the BNSF discharges. The unpermitted coal and petcoke discharges by the BNSF trains into Washington waterways must be brought to a close if we are to fulfill our mission to protect the Gorge.

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I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Portland, Oregon this second day of September, 2013.

Michael Lang

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HON. JOHN C. COUGHENOUR

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF WASHINGTON

SIERRA CLUB, a California nonprofit corporation; PUGET SOUNDKEEPER ALLIANCE, a Washington nonprofit corporation; RE SOURCES FOR SUSTAINABLE COMMUNITIES, a Washington nonprofit corporation; COLUMBIA RIVERKEEPER, a Washington nonprofit corporation; FRIENDS OF THE COLUMBIA GORGE, INC., dba FRIENDS OF THE COLUMBIA GORGE, an Oregon nonprofit corporation; SPOKANE RIVERKEEPER; NATURAL RESOURCES DEFENSE COUNCIL, a New York nonprofit corporation, Plaintiffs, v. BNSF RAILWAY COMPANY, a Delaware corporation, Defendants.	CIVIL No. 2:13-cv-00967-JCC DECLARATION OF POLLY WOOD IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO DISMISS

I, Polly Wood, hereby declare:

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1. I am over the age of 18, have personal knowledge of the following, and could competently testify if called as a witness in this legal action. I am aware that Columbia Riverkeeper, Friends of the Columbia Gorge, and other parties have filed a civil action asserting that Burlington Northern Santa Fe (BNSF) has discharged and is discharging coal, coal dust and/or petroleum coke (petcoke) and their byproducts into Washington waters without a permit in violation of the Clean Water Act. Columbia Riverkeeper and Friends of Columbia Gorge represent my interests in this lawsuit.
2. I make this declaration in support of this litigation because I believe it is necessary to protect the water quality of the Columbia River watershed, where I live and recreate with my family, my husband and eight year old daughter.
3. I reside at 525 Highline Road, Hood River, OR, 97031 in Hood River County. I have lived in Hood River for approximately 11 years.
4. I am a retired pastry chef and former business owner of Polly's Cakes and now spend my time volunteering for several organizations in addition to raising my eight-year-old daughter. I am President of the Board of the Hood River Valley Residents Committee, a local land use advocacy organization that works to protect farm and forest land and to promote livability of the Hood River community by upholding the Oregon Land Use laws. I am a Board Member of Friends of the Columbia Gorge. I also work with the Hood River Library Foundation to put on an annual fundraiser for the local library.
5. I am and have been an active member and supporter of Columbia Riverkeeper for nine years, and have donated annually since 2004. On behalf of Columbia Riverkeeper, I provide annual financial support, attend functions, such as fundraising events, participate in letter-writing campaigns, and respond to various electronic action alerts on matters affecting the environmental health of the Columbia River ecosystem.
6. Columbia Riverkeeper is a non-profit organization that serves as the "watch dog" for the Columbia River. The organization looks after the health of our river, monitors its water

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quality, advocates for its protection, and serves as an advocate to prevent activities that threaten the health of our river. As part of its education mission, Columbia Riverkeeper also sponsors trips and outings for those interested in learning more about the river and the wildlife that depend upon the river.

7. I believe that the burning and transportation of coal is one of the most significant environmental problems that our community faces today. I am aware of and support Columbia Riverkeeper's advocacy work on coal. I am aware that Columbia Riverkeeper staff and/or volunteers have worked to gather coal in the river that has been deposited by passing coal trains.

8. I am concerned about the presence of coal, coal dust and petcoke in the Columbia River and the waters that feed the Columbia River because I believe the presence of coal in the water pollutes the water. I also believe that the coal contains contaminants that pose a threat to the health of the species that use and depend upon the Columbia River.

9. I live and own my own home approximately one mile away from the Columbia River. I have a view of the river from my home. I can also see and hear the coal trains as they pass along the river.

10. I believe the presence of coal in our waterways degrades the value of living in this special place. People largely come to visit and live in this community to engage in recreation activities on the water, whether it be swimming, fishing, wind surfing, kite surfing, paddle boarding, or boating. I believe that the presence of coal in the water would make Hood River a much less desirable place to live and visit if the water continues to be contaminated by coal. This in turn will negatively affect the value of my property as well as the quality of my life in Hood River.

11. My recreational interests and activities primarily take place on or around the Columbia River. I visit the river frequently and intend to visit and use the river on a regular basis. In terms of the transportation of coal on railways by BNSF, I am particularly concerned

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about the coal that is deposted into the Columbia River, Klickitat River, White Salmon River, Coburg Beach, Rock Creek, the mouth of the Hood River and Wells Island. Many of the foregoing waterways are places that I visit and use and are impacted by coal and coal dust pollution from the BNSF coal trains because the coal trains pass adjacent and/or directly over them.

12. I regularly engage in bird watching at the mouth of the Klickitat River where it meets the Columbia River. Particularly, my family and I visit this area in January to view the eagles. The presence of coal in the water or on the beach in this area would greatly diminish my enjoyment of this activity and we likely would refrain from coming at all.

13. My husband and I own an Adirondack guide boat that we regularly use on the Columbia River. We usually use it for day trips on the river and will travel from Hood River to other sites along the Columbia River. We frequently travel up the mouth of the White Salmon River, around Koberg Beach, Rock Creek, and Wells Island on the Oregon side. We also intend to visit other areas in the future. When we get to our destination, we pull our boat up onto the shore and thus our enjoyment of this activity would be adversely affected by the presence of coal in the water or on the shore because it would detract from the natural beauty of the area in which we are recreating and pollute the area as well. My family has no desire to recreate in waters polluted with coal.

14. I frequently bicycle along paths that are adjacent to the Columbia River, in The Dalles and along the Hood River waterfront. One of the reasons I enjoy bicycling this route is to enjoy the views of the River. I would be less inclined to participate in this activity if there is coal in or alongside the river where I bicycle.

15. While I do not personally go fishing, my family consumes fish caught in the Columbia River by Tribal fishermen as a way to support our local economy. The coal in the water, and the heavy metals that come from the coal, will contaminate the fish, thereby harming our local economy and the health of my family. I am especially concerned about the

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health of my daughter, as she is young and her system is more susceptible to contamination from heavy metals. Consuming fish caught from the Columbia River is a treasured part of the culture and history of our community, which is being degraded by the coal deposited into the water by BNSF.

16. My family and I regularly hike and picnic in several places adjacent and around the Columbia River. The viewshed surrounding the Columbia River is astounding and the presence of spilled coal in and alongside the river negatively affects the beautiful views that this region has to offer. This negatively affects me as well as our local economy, as many people travel to this area to view the Mighty Columbia and would be less inclined to do so if the river is polluted with coal. Water-based recreational activities, including but not limited to boating, kayaking, swimming, kite surfing, wind surfing, and paddle boarding, are the basis for the Hood River economy and thus the economic health and vitality of my community is especially vulnerable to activities that pollute the water, such as transporting coal in a manner that allows the coal to spill into the river.

17. Studying the wildlife, especially salmonids, is an activity that my family and I regularly do in the Columbia River area. Specifically, we frequently take my daughter to the Rock Creek area to view salmonids swimming up and down the river as they have done for thousands of years. We assist the salmon if they ever get stuck in low water. This is an important circle of life that my daughter is able to witness and this activity is put in jeopardy by the deposition of coal into the Columbia River.

18. My family, especially my daughter, enjoys swimming in the Columbia River. We frequently swim at the waterfront park in Hood River and wherever we park our boat on our trips up and down the River. As a mother, it makes me very uncomfortable to think that my daughter is endangering her health by engaging in a healthy activity such as swimming in her own backyard.

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19. In early April 2013, I personally saw coal on the side of the railroad tracks near the mouth of the White Salmon River. I have also seen coal on the side of the tracks and in the Columbia River near the confluence with the Wind River in June 2013. I did not collect or take photographs of the coal, but it was disturbing to me to see how much coal was spilled into our River.

20. I believe that BNSF's deposition of coal, coal dust and petcoke into the Columbia River watershed has harmed me because coal in the water negatively affects my ability to engage in recreational activities that I enjoy and threatens the health and economic welfare of the community in which I live. I believe that if the court were to issue a decision requiring BNSF to operate in a manner that ensures that no coal or coal dust is deposited into the Columbia River watershed, my interests in preserving my way of life and protecting the environment in my community would be protected.

I declare under penalty of perjury that all of the forgoing is true and correct.

Executed in Hood River, Oregon, on August 30, 2013.

Polly Wood

Polly Wood

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