Natural Events Policy Documentation of a Natural Event Due to High Winds on 16-Aug-2002 Kennewick, WA

Benton Clean Air Authority

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OVERVIEW

On 16-Aug-2002 a exceedance of the primary 24-hour PM_{10} National Ambient Air Quality Standard (NAAQS) was recorded at Kennewick, WA, PM_{10} State/Local Air Monitoring Site (SLAMS). The concentration was officially reported as 186 µg/m³ at standard atmospheric conditions. A particulate-laden air mass associated with a dissipating cold front moved south across the Columbia Plateau in the early morning hours of 16-Aug-2002. Reports of wind speeds and gusts throughout the area to the north and northwest of the Tri-Cities provide adequate evidence that conditions were sufficient to produce the 900 (ug/cm3) PM_{10} concentration measured in Kennewick, Washington, given a vulnerable landscape susceptible to soil erosion.

Low wind speeds from the north, into the Tri-Cities, from 0500 to 0700 were insufficient to raise significant dust, but were sufficient to transport dust previously raised by strong winds to the northwest. Moreover, observations of large temperature-dew point spreads during the period of decreased visibility and lowered ceilings at the Pasco Airport rule out the possibility that water-formed clouds produced the restrictions to visibility.

PM_{10} from beyond the immediate area was transported into Kennewick and caused the PM_{10} exceedance on 16-Aug-2002. Available forecasts and numerical weather prediction model output of meteorology coupled with surface observations and ambient concentrations support this hypothesis. An exact quantification of the source contributions is not available. The Benton Clean Air Authority (BCAA) believes that the 16-Aug-2002 event is a “natural event” in accordance with the EPA Natural Events Policy.

Natural Events Policy

The Natural Events Policy (NEP) was issued in May 1996 to provide an avenue of response to PM_{10} air quality data that are due to uncontrollable natural events. Under NEP provisions PM_{10} attributable to a natural event can be excluded from an attainment or non-attainment decision. The NEP is applicable when PM_{10} data is due to uncontrollable natural events and the dust originates from non-anthropogenic sources or from contributing anthropogenic sources controlled with best available control measures (BACM)

The two basic requirements of the NEP are:

1) The states must develop a Natural Events Action Plan (NEAP) to deal with future PM_{10} NAAQS exceedances.

2) The states must also establish a clear and casual relationship between the observed natural event and the observed exceedance and document the event.

Natural Events Action Plan

Washington State's NEAP to address PM_{10} from natural events occurring in the Columbia Plateau region of eastern Washington was a result of a larger number of PM_{10} NAAQS exceedances in this region in the period from the late 1980's and early 1990's. Agricultural fields upwind of PM_{10} monitoring sites were identified as the principal sources of windblown dust. The Washington State Department of Ecology's Air Program division developed the initial NEAP in 1998.

Definition of High Wind Event

The 2003 NEAP refined the definition of high wind event for Washington State in accordance with the provisions of the NEP allowing the states to determine this definition. This provision recognizes the multiple variables that affect the wind erosion processes that result in windblown dust and the generation and transport of PM_{10}, which geographically differs. Following is the definition of a "high wind event" from pages A1-A4 of the Washington State Columbia Plateau Windblown Dust Natural Events Action Plan (Ref 5):

"A high wind event occurs when the wind entrains and suspends dust to the extent that concentrations of PM_{10} are elevated. This occurs when the average hourly wind speed at 10m is 18 miles per hour or greater for two or more hours; or in excess of 13 miles per hour for two or more hours when conditions of higher susceptibility to wind erosion exist (see attachment A1). A high wind event that exceeds PM_{10} standard is a natural event."

This definition recognizes the concept that the wind speed threshold for wind erosive processes on soil to cause elevated PM_{10} concentrations in the air is variable. This variability depends on multiple variables related to soil characteristics, wind gustiness, soil surface residue cover, moisture content, and others. Appendix A and Attachment A1 of the Columbia Plateau NEAP documents the research and explains the logic behind this two-stage "high wind event" definition. The high wind event definition also necessarily includes the concept that the intensity of the wind event is a combination of wind speed and significant duration (sustained wind).

Accordingly, the amount of detail in the event documentation required by the NEAP varies with the category (18 mph for ≥ 2 hr; or 13 mph for ≥ 2 hr under higher wind erosion susceptibility) of high wind event definition. For the "18 + 2" category the documentation burden is less because of the more clear cut association of the observed PM_{10} data and the wind speed profile. The wind speed profile contains wind speed, wind direction, and duration and essentially is a data plot of wind speed and direction against a period of time. Antecedent precipitation preceding the day of the event completes the "18 + 2" data set. The higher wind speed event more easily meets the "clear and casual" criteria of the Natural Events Policy.

The “13 + 2” category within the high wind event definition is more problematic with respect to establishing a simple and straight forward link between the wind event and elevated PM_{10}. The wind erosive forces are more transient, the transport mechanisms less clear, and the meteorological phenomena driving the process are spatially and temporarily complex. The number, geographic distribution and complexity of the meteorological measurements needed to describe the event are greater. The “clear and casual” criteria is more difficult to establish. These complexities will require more sophisticated methodology to reveal the dynamics of the event. Regional scale meteorological modeling coupled with PM_{10} generation (emission) and transport modules will likely be necessary. Other data to establish the link of an event to elevated PM_{10} are identification of probable sources such as fires or other remotely located source areas. The goal is to link probable source areas via regional scale transport models and such output as back-trajectory analysis from the PM_{10} monitoring site that generated the observed PM_{10} NAAQS exceedance.

The NEAP has several purposes:

- Development of procedures for taking appropriate, reasonable measures to safeguard public health when natural events occur.
- Responsibility to assure that emission controls are applied to sources that contribute to exceedances of the PM_{10} NAAQS, when those controls will result in fewer violations of the standards.
- Authorization for documentation to be submitted to request designation of an exceedance of the NAAQS for PM_{10} as being the result of a natural event.

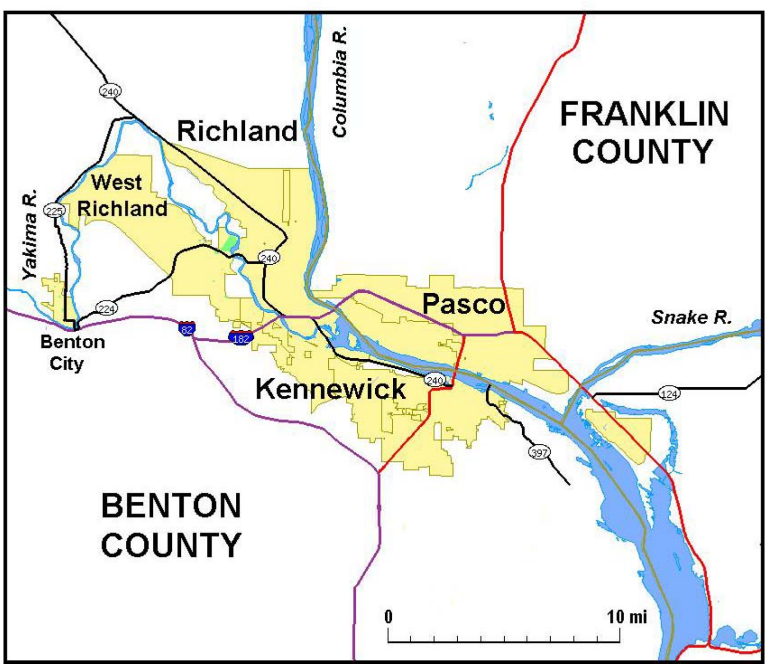
Emission controls include BACM development and implementation. The development or implementation of BACM for anthropogenic sources of fugitive dust within three years of the violation is an important goal of the NEAP.

For agricultural sources, BACM is more commonly referred to as Best Management Practices (BMPs). A variety of management practices to control wind erosion and associated PM_{10} emissions were one of the expected outcomes of the Columbia Plateau PM_{10} Project. To qualify as a BMP, the practice must be proven to reduce wind erosion significantly below that which would occur with bare and tilled soil under similar weather conditions. Meteorological and climatological conditions strongly affect effective wind erosion or dust control on agricultural lands. Maintaining soil stability on agricultural fields is a problem in the Tri-Cities region only during the most vulnerable times, such as crop planting and harvesting, or for other tillage operations that leave the soil vulnerable to wind erosion.

GENERAL DESCRIPTION OF COLUMBIA PLATEAU

The eastern half of the state lies in the rain shadow of the Cascade Mountains making the region a semi-arid desert. A large basalt plateau in eastern Washington surrounds the confluence of the Snake River with the Columbia River. This plateau is bounded by the Selkirk Mountains and Okanogan Highlands on the north, the Wallowa Mountains on the south, Cascade Mountains on the west, and the west slope of the Bitteroot Range on the east. The Cascade Mountains extract moisture from fronts moving inland from the Pacific Ocean and leaves the Columbia Plateau very dry compared to the western areas in Washington. Precipitation varies from 6 inches per year at the center of the plateau to over 30 inches per year along the perimeter of the plateau. Vegetation types reflect the moisture distribution pattern.

Figure 1: The Eastern Washington Columbia Plateau Area



The perimeter of the Columbia Plateau is covered with forests which quickly changes to savanna and then steppe as one nears the center of the plateau. Much of the area outside of the forested lands have been tilled and converted to dryland agriculture and range. The central part of the Columbia Plateau is the driest and in that area irrigation is required.

Dryland and Irrigated Agriculture

There are two major types of wheat planted in the Columbia Plateau area – winter wheat and spring wheat. Winter wheat is planted in September or October and harvested the following summer. Spring wheat is planted in April or May and is harvested in August or September. Both varieties of wheat are grown throughout the Columbia Plateau, often growing very near to the urban areas. The arid conditions of this area often necessitates that a specific method of farming, called fallow farming, be used to maximize water conservation in the soil. After a wheat crop is harvested in late summer, the land is worked and then allowed to lie dormant, or fallow, until the following summer or fall. Weeds are controlled by chemical herbicide, which is called chem-fallow or with an implement called a rod weeder, which is called traditional fallow. This 12-14 month fallow period allows time for precipitation to replace the depleted soil moisture needed to grow the new wheat crop. The new crop is usually planted on the fallowed land in September or October. However, prolonged periods of little or no precipitation can extend the dryland wheat planting into November or December because there simply is not enough moisture in the soil for the next cropping cycle. During the period between the harvest date and the date of the new planting, dryland wheat lands are vulnerable to wind erosion. This period coincides with the higher probability of high wind speeds throughout the Columbia Basin.

These agricultural soils remain vulnerable until there is sufficient moisture in the soil to promote the growth of the new wheat crop. A similar situation occurs with the spring wheat crop, which is vulnerable in the spring during planting. A lack of moisture in the soil over the winter months can delay the growth of the spring wheat crop and leave these areas vulnerable to wind erosion as well. Fields intended for winter wheat can become spring wheat plantings if precipitation is lacking or inadequate for fall planting of winter wheat. Winter-kill of winter wheat from severe cold weather can also result in fields being planted to spring wheat.

As an alternative to dryland farming, in areas where irrigation is available, irrigated farming is quite common throughout the region. Crops that normally would not grow in this arid climate have become very productive due to the center pivot irrigation system. Annual irrigated crops, including irrigated wheat, are usually planted in the spring, and harvested in the summer or fall, which periodically exposes the soil to wind erosion. Perennial irrigated crops such as alfalfa generally have less wind erosion exposure because the fields have vegetative cover continuously for several years. Because irrigated crops have access to water for the majority of the year, they are generally less vulnerable to wind erosion. However, during and after harvest of these crops, when crop residue in the fields is very low, wind erosion potential can be very high.

Wind Erosion of Agricultural Lands

Agricultural fields are the principal contributors to windblown dust events in the Columbia Plateau area. A windblown dust event occurs because of the interplay of wind, seasonal variations in landscape vulnerability to wind erosion, and other weather variables. Operational activities, which disturb soil on agricultural fields function principally not as primary dust generators, but primarily increase the susceptibility of the soil to wind action. In most cases, however, there is no one factor that shows a direct causal effect for wind erosion or dust events.

The period of highest potential for higher wind speeds, late summer through early spring, corresponds to the periods of maximum agricultural field susceptibility to wind erosion. This is the case because crop residues are lower overall because of spring planting or fall harvest. Conversely, the summer period of lower frequency of higher wind speeds corresponds to the period of maximum agricultural field stability against wind erosion because of higher overall crop cover during the peak crop growing season. These two circumstances combine to make the probability of significant windblown dust events, with agricultural origins, greater in the period from September through April. The latter is verified by the pattern of previously observed PM_{10} NAAQS exceedances, which are most frequent from late summer through early spring.

These seasonal effects are manifested in both irrigated lands and dryland wheat. Generally, irrigated fields are vulnerable during the spring when planting begins and during the late summer after harvest. Unless wind erosion control is accomplished via significant plant residue left after harvest, an established cover crop, or some other control mechanism, windblown dust can be significant from irrigated fields. On dryland wheat fields, a series of events such as drought, winterkill from lack of snow cover, or a combination of these will diminish the amount of crop residue available to help hold soil in place. The amount of control of soil erosion on winter wheat lands is almost entirely dependent upon the weather, which affects the amount of crop residue, soil moisture, and snow cover which in turn determines the soil susceptibility to wind. Regardless of the crop type or farming practice, the chief determinant of susceptibility to windblown dust is the amount of vegetative cover on the soil.

DESCRIPTION OF 16-AUG-2002 EVENT

Monitoring for PM_{10} has occurred in the Tri-Cities area since about 1988 using Anderson size-selective high-volume PM_{10} FRM samplers. In 1991, the monitoring frequency was increased to daily sampling. In 1994, the BCAA installed a Tapered Element Oscillating Microbalance (TEOM) for tracking hourly concentrations of PM_{10}.

PM_{10} Levels in Eastern Washington

PM_{10} TEOM monitors in Eastern Washington cities on 16-Aug-2002 were impacted from high concentrations with the Wenatchee and Yakima areas measuring the highest concentrations levels in the state. (Figure 2) PM_{10} concentrations rose sharply between 0500 and 0800 PST and the highest concentrations in Eastern Washington impacted monitors between 0500 and 1000 PST. By 2000 PST the PM_{10} levels had returned to near normal levels. Unfortunately Kennewick SLAMS (State and Local Air Monitoring Station), had the only PM_{10} FRM (Federal Reference Monitor) that was operating in the impacted areas of Eastern Washington thus, Kennewick recorded the only exceedance of the PM_{10} NAAQS (National Ambient Air Quality Standard). These TEOM traces clearly demonstrate that this windblown dust event was regional in the Columbia Plateau and the dust recorded on the Kennewick PM_{10} FRM originated principally outside Benton County.

Figures 3 and 4 show NOAA (National Oceanic and Atmospheric Administration) satellite dust images at 1545 UTC (Coordinated Universal Time) and 2144 UTC respectively, which is 8:45 AM and 12:44 PM. In Figure 3 the dust can be seen as a yellowish streaking caused by strong winds from the north northwest. In Figure 4 the dust is illustrated in the same area by a white color. The photos make it obvious that a large amount of dust was moving off of areas in the north central Columbia Plateau. Although the images don't show the dust clouds impacting the Tri-Cities directly, the images do indicate the amount of dust present in the air over the Columbia Plateau. It should be noted that these satellite images show the most intense and severely disturbed surface conditions manifested as visible dust clouds from several hundred miles altitude. Less intensely affected areas in the vicinity around and downwind of the visible plumes obviously affected a large portion of the Columbia Plateau as seen from the TEOM traces in Figure 2.

Figure 2: Regional PM-10 Concentrations

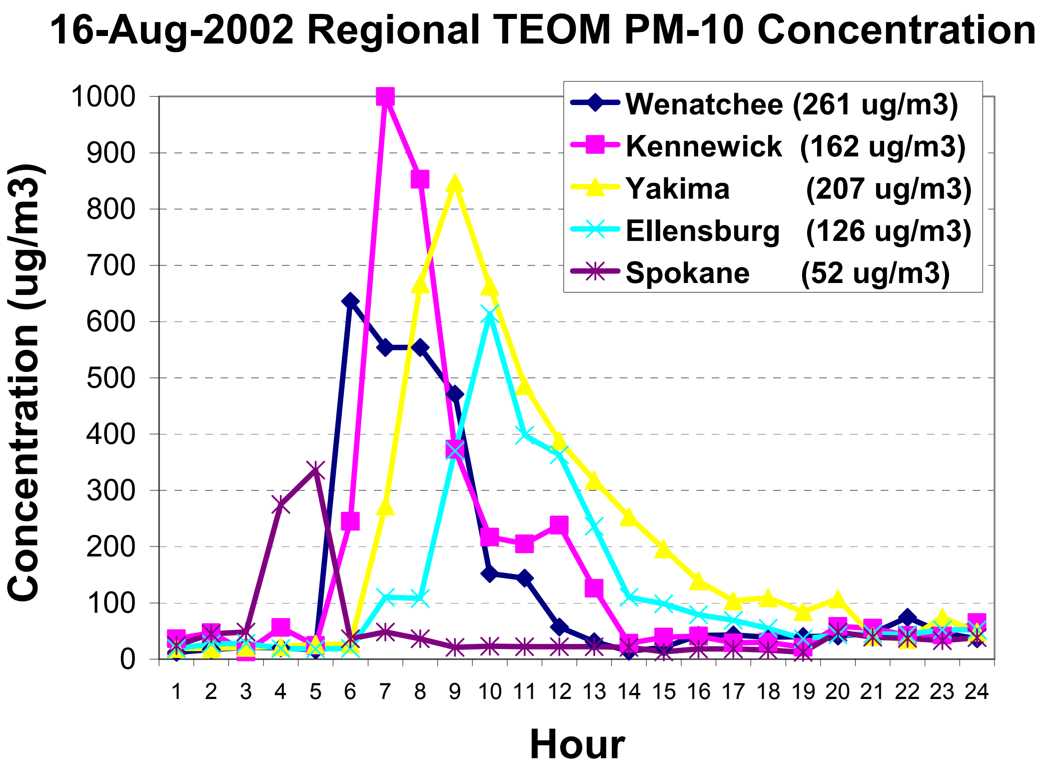


Figure 3: Columbia Plateau Dust Clouds

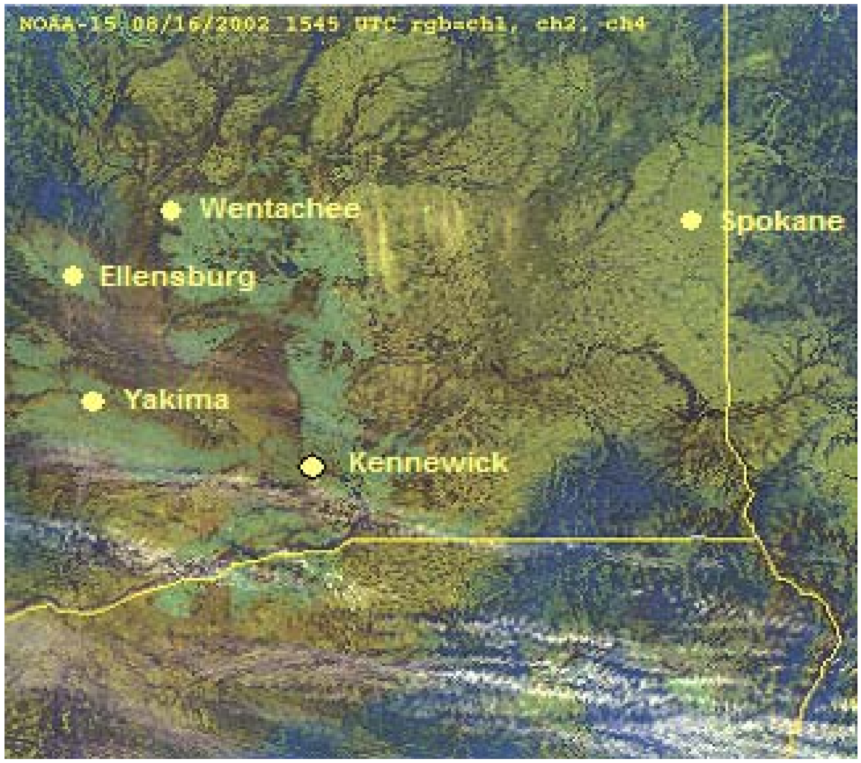


Figure 4: Columbia Plateau Dust Clouds (cont.)

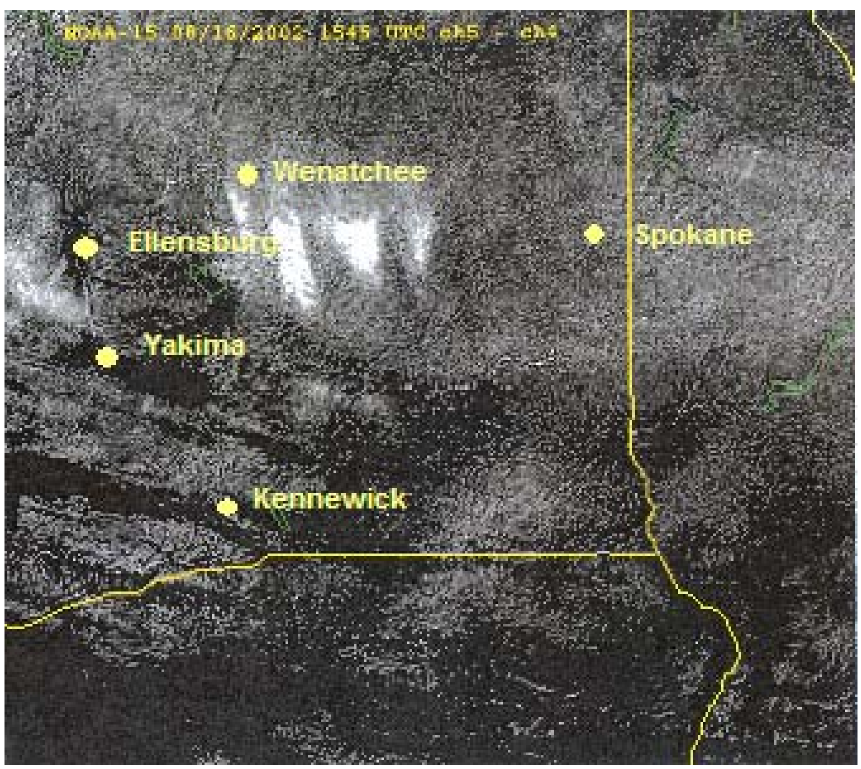


Figure 5 below is a photograph of the Columbia River in Pasco looking towards Kennewick. The photo shows large amounts of dust in the air on 16-Aug-2002.

Figure 5: Dust in the air 16-Aug-2002

Filter Analysis

The PM_{10} High Volume FRM sampler from 16-Aug-2002 uses a quartz fiber filter. This filter was analyzed by both the Manchester Environmental Laboratory and the RJ Lee Group. Both analyses returned consistent results. RJ Lee Group analyzed the filter using scanning electron microscopy (SEM) and computer controlled scanning electron microscopy (CCSEM) and thermal/optical carbon methods.

The manual SEM examination confirmed that the sample was comprised primarily of silicon(Si)/aluminum(Al) - rich particles. The predominant Si/Al-rich particle type was indicative of earth crustal material. The CCSEM results (Table 1) also indicated that the majority of the sample was comprised of Si/Al-rich particles often containing potassium, iron, magnesium and/or calcium either singularly or in combination. Si/Al-rich and Si-rich particles are indicative of earth crustal material, such as soil. Carbonaceous material and metal particles accounted for a trace of the total particle weight.

The filter was also analyzed using the Thermal/Optical Carbon Analyzer by the Manchester Environmental Laboratory to provide additional information on the organic and elemental carbon components (Table 2).

Table 1: Particle number and chemical composition analysis by computer controlled scanning electron microscopy.

Classes	Particle Number	Number %	Weight %
Si/Al Types	945	74.9	84.9
Si-rich	136	10.1	10.3
Si/Mg	11	1.7	0.6
Ca-rich	29	4.2	0.8
Fe-rich	23	3.7	1.7
Cu-rich	7	1.2	0.1
C-rich	21	2.7	0.4
Misc.	13	1.5	1.1
Totals	1185	100	100

Table 2:

Total OC Mass (µg)	Total EC Mass (µg)	Total Carbon Mass (µg)	Total Carbon Fraction (%)	Total OC Fraction (%)	Total EC Fraction (%)
14494.3	1145.4	15639.6	5.4	4.98	0.39

In summary, the manual SEM, CCSEM, and thermal optical results of the 16-Aug-2002 PM_{10} collected from the Kennewick ambient monitor indicate that crustal material was responsible for the vast majority of the sample mass. These results are consistent with the conclusions of the carbon analysis provided by the Manchester Environmental Laboratory, which showed only approximately 95% of the mass was non-carbonaceous.
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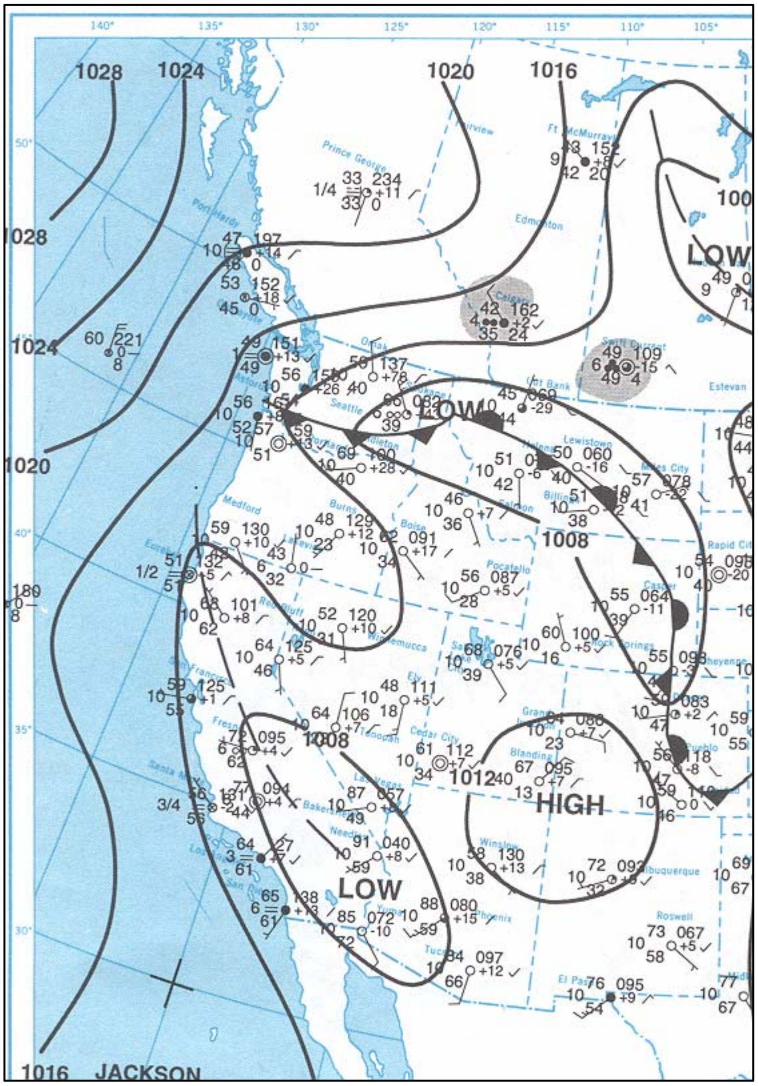
WIND CONDITIONS IN COLUMBIA PLATEAU

This section describes the major meteorological factors that affected the occurrence of the windblown dust event and an exceedance of the PM_{10} NAAQS on 16-Aug-2002 in Kennewick, WA.

Synoptic Weather Pattern

A cold front, which is centered over the northern Idaho panhandle, which is illustrated in the synoptic map in (Figure 6), passed over the Tri-Cities area at approximately 0500 PST on 16-Aug-2002. The low pressure system is characteristically a counter-clockwise wind pattern, caused air flow from the North across areas of North Central Washington and the Columbia Plateau. High wind gusts occurred during the front passage as shown in the surface observations.

Figure 6: Synoptic Map 16-Aug-2002



Forecast Discussion

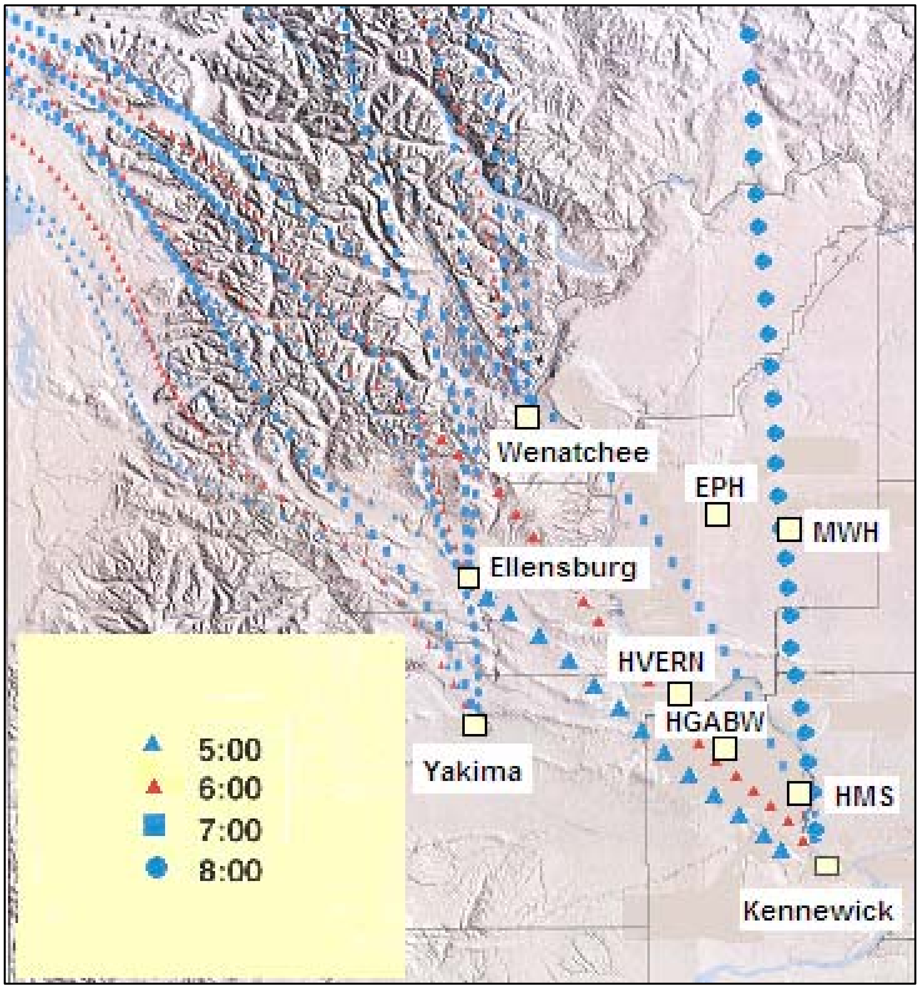
The 20:30 PST, 15-Aug-2002 forecast discussion from the National Weather Service (NWS), Spokane, Washington show that high winds were anticipated across Central Washington. The discussion describes a short wave trough moving across the area late 15-Aug or early 16-Aug-2002. Winds, cooler temperatures and little if any cloud cover were forecast. Six hours later, the 0230 PST, 16-Aug-2003, discussion further describes the dry short wave enhancing pressure gradients across Central Washington. No increases in winds is noted – but were forecasted within the next couple of hours. A red flag warning for strong winds and low relative humidity were issued for all fire zones.

An updated forecast discussion was issued at 0400 PST 16-Aug-2002. Increased winds in the Okanogan Valley, which is located in the north central portion of the Columbia Plateau near the border of Washington State and Canada, were noted prompting the issuance of a high wind warning. Breezy/Windy/Very Windy weather coupled with low relative humidity were forecasted, which prompted a red flag warning for strong winds and low relative humidity were issued for all fire zones. The 0900PST 16-Aug-2003 forecast discussion describes dry north to northwest flow aloft following the vigorous short wave. The strongest winds occurred in the Okanogan Valley around 0200 PST. The discussion notes, however, contain many reports of winds and tree limbs down overnight throughout northeast Washington.

Back Trajectory Analysis

Figure 7 shows back trajectories built from the Pacific Northwest MM5 (meteorological model) forecast output. Back trajectories for 0500, 0600, 0700 and 0800 PST on 16-Aug-2002 were constructed for Yakima, Wenatchee, Ellensburg and Kennewick. Select surface observations are highlighted as well. The back trajectories show a forecast shift in wind direction at Kennewick, from the northwest through the north, from 0500 to 0800 on 16-Aug-2002. Surface observation highlights show winds to the northwest through north of Kennewick ranged from 18 to 22 MPH for several hours. Peak gusts ranged from 31 to 44 MPH.

Figure 7: Back Trajectory Analysis 13-Aug-2002



Wind Profiles in the PM_{10} Source Area and the Urban Receptor Area

Data from various meteorological stations throughout the area are consistent with the above forecasts and observations. Table 3 identifies the meteorological stations, their geographic proximity to the Tri-Cities, the average wind speeds and gusts for the identified time frame, as well as the time and wind direction associated with the peak gust. (See Figure 7 for locations)

Table 3:

Location	Relative to Kennewick	Time	Avg (MPH): Wind speed/gust	Peak Gust (MPH)	Time of Peak Gust
(EPH) Ephrata Municipal Airport	75 miles NNW	0500-0450	22/32	44N	0430
(HVERN) Vernita Bridge Hanford	45 miles NNW	0100-0455	18/24	31NW	0140
(MWH) Moses Lake/ Grant County Airport	65 miles WNW	0250-0450	20/30	38NNW	0420
(HGABL) Gable Mtn. Hanford	40 miles NW	0100-0525	20/28	38 WNW & N	0140 and 0525
(HMS) Hanford MET station	25 miles NW	0500-0450	17/NA	NA	NA

Table 4 shows the meteorological data at Kennewick and Pasco for the same time period. Winds were mild and quite varied near the Tri-Cities. Wind directions measured at Kennewick during this time range from ESE through S to W and ENE. Available data for Pasco shows early morning winds were from the ESE and WSW.

Table 4:

Location	Relative to Kennewick (miles)	Time (PST)	Avg (MPH): Wind speed/gust	Peak Gust (MPH)	Time of Peak Gust (PST)
Pasco	2 Miles NNE	0023-0453	5/NA	NA	NA
Kennewick	0	0010-0455	4/6	9 SW	0325

Tables 5 and 6 summarize meteorological data from 0450 to 0655 for the above meteorological stations. From 0455 to 0655 wind speeds and gusts remain quite similar to those reported earlier in the morning. Wind directions, however, veer to a more northerly direction at all locations except Kennewick. Northerly winds are recorded at Kennewick beginning at 0555. Most notably, winds coming into Pasco during this time (Table 4) are consistently from the north-northwest through north. The wind speeds were insufficient to raise significant dust and do not support that PM_{10} in the immediate area caused the PM_{10} exceedance on 16-Aug-2002.

Table 5:

Location	Relative to Kennewick (miles)	Time (PST)	Avg (MPH): Wind speed/gust	Peak Gust (MPH)	Time of Peak Gust (PST)
(EPH) Ephrata Municipal Airport	75 miles NNW	0500-0450	18/29	31N	0510
(HVERN) Vernita Bridge Hanford	45 miles NNW	0455-0655	10/16	22NNE	0540
(MWH) Moses Lake/ Grant County Airport	65 miles WNW	0350-0550	19/27	30N	0450
(HGABL) Gable Mtn. Hanford	40 miles NW	0455-0655	23/31	38 N	0525
(HMS) Hanford MET station	20 miles NW	0450-0650	19/NA	NA	NA

Table 6:

Location	Relative to Kennewick (miles)	Time (PST)	Avg (MPH): Wind speed/gust	Peak Gust (MPH)	Time of Peak Gust (PST)
Pasco	2 Miles NNE	0453-0653	9/NA	NA	NA
Kennewick	0	0455-0655	3/6	10 N	0655

The contrast between the meteorology reported early in the morning at the Pasco airport and those at Vista Field in Kennewick yields important additional information for understanding this event. Analysis of wind speed, temperature, cloud height, and visibility observations support the hypothesis of a dust cloud moving into the area from the north.

The two airports are on opposite sides of the Columbia River and are approximately five miles apart. The Vista Field observations of light winds (3 to 6 mph) primarily from the south, and east-southeast to west-southwest support the formation of nocturnal down slope winds on the northern side of the Horse Heaven Hills which are located to the south of the airport. Such winds are typically shallow and limited to areas near the slope. At the same time, wind speeds at the Pasco airport, which started out with strong west to southeast winds at midnight, dropped to calm by 0200PST in the cold pool of air that formed under the clear skies and remained so until 0453PST when northerly winds had increased to 7 MPH. Air temperatures at both airports show the cooling expected on a clear night with temperatures dropping ten or more Fahrenheit degrees between midnight and 0500. The light winds at Vista Field limited the cooling to just 11 degrees, temperatures at the Pasco airport which reported less winds dropped by 16 degrees.

Table 7 illustrates the likely dynamic associated with the north to south movement of the dust cloud in the context of the observed meteorology. At 0523 PST the Pasco airport reported both a change in sky conditions (which triggered the need for a special observation) and a sharply increased temperature. Sky conditions were reported at six-eighths coverage with a height of 1500 feet and ten mile visibility which changed to clear and no clouds below 12,000 feet but three mile visibility dropped at 0537. Visibility remained less than three miles for the next hour and a half and the reported ceiling dropped as low as 400 feet.

Table 7: Pasco and Kennewick Conditions

Pasco								Kennewick				
Time (PST)	Wind Speed (MPH)	Wind Direction (degree)	Air Temp (°F)	Dew point Temp (°F)	Cloud Cover	Cloud Height (100 ft.)	Visibility (miles)	Time (PST)	Wind Speed (mph)	Gust (mph)	Wind Direction (degrees)	Air Temp (° F)
2353	13	250	73	51	0	120	10	0100	3	7	W	78
								0025	3	4	S	76
								0040	4	7	S	75
0053	10	150	71	48	0	120	10	0100	3	6	ESE	74
								0125	3	4	SW	72
								0140	5	7	SW	71
0153	0	0	67	50	0	120	10	0155	4	7	WSW	71
								0210	4	7	WSW	71
								0225	5	7	WSW	71
								0240	5	7	WSW	72
0253	0	0	65	51	0	120	10	0255	5	7	WSW	72
								0310	5	7	SW	70
								0325	5	9	SW	71
								0340	4	8	SSW	70
0353	3	NA	60	52	0	120	10	0355	2	34	SSW	70
								0410	3	5	SW	69
								0425	3	8	ENE	67
								0440	2	3	SW	67
0453	6	360	57	52	0	120	10	0455	3	4	SW	67
0523	8	340	63	55	6	15	10	0525	2	3	SSE	65
0537	8	330	63	54	0	120	3	0540	3	4	SSW	65
0553	8	33	65	53	0	120	2	0555	3	4	NNW	65
0600	8	330	64	52	8	8	3					
0609	9	340	64	52	8	6	2					
0630	13	340	66	54	6	4	2	0625	3	7	NNW	67
								0640	3	7	NW	69
0653	8	340	67	54	1	120	3	0655	6	10	N	70
0718	6	340	72	52	0	120	3	0725	6	10	NNW	70

The higher winds (9 to 15 mph) associated with the dust-laden air upon encountering the slower moving and calm air in Pasco will be forced upwards in the convergence zone carrying some dust with it (see the 0523 Pasco observation). The upward moving air will be compensated by the downward moving air both to the front and rear of the convergence zone. The downward moving air about the main dust plume will serve to decrease thickness and is supported by the observations at 0537 and 0553 which report low visibilities but no sky cover below 12,000 feet. As the dust plume moves on and the convergence zone between the stronger northerly winds and the calm (and on the south side of the river, southerly) winds leave the Pasco area, the plume thickness increases as shown by the combination of low cloud heights of 400 to 800 feet and low visibility of two and three miles.

Ephrata Municipal (EPH) and Moses Lake/Grant County (MWH) airports share similar landscape and proximity to the Tri-Cities although the recorded wind conditions are somewhat different. EPH recorded the longest duration of the more intense winds the morning of 16-Aug-2002. Wind directions during this time ranged from WNW through North, generally upwind of the Tri-Cities. Between EPH and the Tri-Cities lie portions of Grant, Adams and Franklin Counties.

Over 600,000 acres of wheat are harvested annually among the three counties. Mid-August is nearing 12 months exposure of summer- fallow in approximately 200,000 to 300,000 acres in this area. By mid-August several weeks of high temperatures and minimal precipitation are the usual weather pattern. These summer-fallowed fields are the most likely and most prone to wind erosion and windblown PM_{10}. The satellite photos shown in Figures 3 and 4 indicate that fields in north-central Columbia-Plateau were most likely a contributor to the dust cloud bearing PM_{10} that was transported into Kennewick.

Vernita Bridge, Hanford (HVERN) and Gable Mountain, Hanford (HGABL) also recorded moderately strong winds with strong gusts. Both share similar landscape and proximity to the Tri-Cities. Both are geographically located within the Hanford Reservation and lie on the outer-most portion of the area burned in 2000. Some of the burned landscape may yet remain vulnerable to wind erosion of soil. Additionally, several active sand dunes in the Hanford Reservation provide potential for lofting of PM_{10}.

The data reveals the following scenario likely caused the PM_{10} exceedance in Kennewick on 16-Aug-2002. , based on transport of PM_{10} from wind eroded soils. Between midnight and 0500PST high winds, to the northwest through the north of the Tri-Cities, lofted PM_{10} (both crustal components and fragmented carbon particles) from a vulnerable areas of the landscape into the atmosphere. From 0500 to 0700, winds consistently out of the NNW through north, as measured in Pasco, transported the previously lofted material into the Tri-Cities area.

LANDSCAPE STABILITY CONDITIONS IN THE COLUMBIA PLATEAU

Antecedent Precipitation

The Columbia Plateau received no measurable precipitation amounts in the 72 hours preceding the 16-Aug-2002 exceedance. Precipitation records from 7 Pacific Northwest Cooperative Agricultural Weather Network Stations (AgriMet) in the Northern Columbia Plateau show that there was no precipitation in up to 48 days before the exceedance date of 16-Aug-2002 (Table 8). The temperature in the six months prior to the exceedance was also above average. The lack of rainfall in the months Jul.-Aug.2002 coupled with above average temperatures and average wind speeds during the period Jul.-Aug. 2002 combined with other factors, such as agricultural field operations, set up a vulnerable landscape situation primed for wind erosion when a wind event occurs in the Columbia Basin area.

Table 8:

AgriMet Station	Days with no measureable precipitation
Lind	48
Odessa	39
George	39
Grand Coulee Dam	39
Manson	36
Chief Joseph Dam	39
Omak	33

Most Probable Agricultural Activities Affecting Landscape Stability

Several agricultural operations in the area that could contribute to lower landscape stability in the period near 16-Aug-2002 would include operations in dryland wheat areas and activity in irrigated areas.

One such soil disturbing activity is spring wheat planting, spring potato planting that can leave which leaves minimal crop residue and would be expected to loosen the soil surface before the 16-Aug-2002 event. Frequently these early harvested potato fields are tilled in preparation for planting of a second crop for the growing season. If not recently irrigated these fields could have a dry, bare surface vulnerable to wind erosion. There is no practical way to determine the amount of spring wheat planting but this activity, if occurring, could contribute to windblown dust.

The arid climate in the wheat producing land in the areas of eastern Washington, make fallow farming a necessary water harvesting method. The exposed soils in fallowed areas were potentially susceptible to wind erosion on 16-Aug-2002. The previous years dryland wheat yields, which also determines the amount of straw residue available for holding the soil against the wind in the subsequent fallow period. Some early preparation or late summer weed control could disturb summer fallow fields and increase their vulnerability to wind erosion. The most probable sources of windblown dust and most vulnerable fields are, as previously mentioned, summer fallow fields with marginally adequate or inadequate surface crop residue.

Summary of Landscape Stability

Overall, the landscape stability of the eastern Columbia Plateau agricultural PM_{10} source area on 16-Aug-2002 was sufficiently low to allow wind erosion with the combination of below-normal antecedent precipitation and agricultural operations disturbing the soil.

Surface soils were subject to wind erosion and PM_{10} emissions. Sustained winds blowing across these unprotected and unstabilized soil surfaces cause soil particles to become airborne and transported into the Tri-Cities urban area even when BACM and BMP are being used (Figure 6a). Fallow fields with in-sufficient residue from previous wheat harvest were also subject to high wind speeds.

BACM IN THE COLUMBIA PLATEAU

The 2002 NEAP (under development) defines BACM for agricultural fields as conservation programs and practices that abate or minimize wind erosion. A more practical working definition is the USDA Conservation Programs, especially the Conservation Reserve Program (CRP) supplemented by incentive based implementation of wind-erosion BMP's. The Conservation Technology Information Center (CTIC) Core-4 program puts together county level data with a National Crop Residue Management Survey. Core-4 tracks conservation (no-Till, Ridge-Till, Mulch-Till) and conventional (0-15% and 15-30% residue) tillage practices and enrollment in CRP.

The CTIC's Core 4 program shows that farmers in the Columbia Basin Counties participate in wind erosion conservation programs and implement conservation practices promoted by USDA's Natural Resource Conservation Service (NRCS and Washington State University's (WSU) CP3. enhancing wind erosion conservation measures in priority counties of the Columbia Plateau, Washington.

The BCAA determines that BACM for agricultural fields was implemented in the Northern Columbia Basin on 16-Aug-2002.

CONCLUSIONS

From the evidence presented, the following conclusions can be drawn:

1. Agricultural areas in the Columbia Plateau were subjected to high wind speeds on 16-Aug-2002. A combination of standard meteorological observation analysis, back trajectory analysis, and TEOM trace analysis in a geographic area widely separated across the Columbia Plateau presents a picture of a regional windblown dust event and dust transport which resulted in the observed PM_{10} NAAQS exceedance at Kennewick WA.
2. Agricultural fields, which were highly susceptible to wind erosion during the 16-Aug-2002 wind events, included dryland wheat fields, irrigated areas disrupted by harvest and some fallowed fields with insufficient crop residue were blowing most severely.
3. The combination of the wind event, which had the necessary wind speed, duration, and direction to generate and transport PM_{10}, and the vulnerable landscape, caused the 16-Aug-2002 exceedance. Although the lowered landscape stability was principally due to agricultural operations, any unprotected area of soil surface elsewhere in the landscape would have potential to contribute to the exceedance.
4. The lack of direct observational evidence of other significant emission sources (other than windblown fugitive dust from agricultural fields) and the acknowledgment that the Columbia Plateau is, in general, highly susceptible to high wind events, show that windblown dust is the most probable source of the PM_{10} NAAQS.
5. Based upon these conclusions, the BCAA considers the PM_{10} concentration recorded on 16-Aug-2002 to have been caused by a high wind natural event and requests that the data for this date be flagged as such in the AIRS database.

ABBREVIATIONS AND ACRONYMS

BACM................Best Available Control Measures

BMP ....Best Management Practices

SLAMS..............State and Local Air Monitoring Station

EPA...................U.S. Environmental Protection Agency

BCAA ....Benton Clean Air Authority

BFWWCAPCA ..Benton Franklin Walla Walla Counties Air Pollution Control Authority, renamed BCAA in 1995

MET...................Meteorological

NAAQS.............National Ambient Air Quality Standard

NOAA…………..National Oceanic and Atmospheric Administration

PM_{10}..................Particulate Matter, 10 microns in diameter

Ecology ....Washington State Department of Ecology

PST ....Pacific Standard Time

NEP...................Natural Events Policy

NEAP ....Natural Event Action Plan

MOA..................Memorandum of Agreement

RACM................Reasonably Available Control Measures

FDP...................BCAA Fugitive Dust Policy

HMN..................Hanford Meteorological Network

PAWS................Public Agricultural Weather System operated by Washington State University

CFR...................U.S. Code of Federal Regulations

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