Washington State Regional Haze State Implementation Plan

Appendix I

Use of 0.5-km Grid Spacing to Evaluate the Impacts of Best Available Retrofit Technology-Eligible Units at Alcoa Wenatchee Works on the Alpine Lakes Wilderness

Use of 0.5-km Grid Spacing to Evaluate the Impacts of Best Available Retrofit Technology-Eligible Units at Alcoa Wenatchee Works on the Alpine Lakes Wilderness

As discussed in section 11.4.1, Alcoa Wenatchee Works proposed, and the Washington State Department of Ecology (Ecology) accepted, refinements to the Washington-Oregon-Idaho BART Modeling Protocol[1]. Specifically, Ecology accepted an alternative meteorological data file, which used a finer grid size than the default grid size specified by the protocol, and the use of an alternate version of CALPUFF. The reasons for accepting these refinements are discussed below.

Alcoa Wenatchee Works is an aluminum smelter located within the Columbia River Valley (Figure 1). About 20 kilometers (km) upstream from the smelter, the valley forks with one branch heading northwest toward the Alpine Lakes Wilderness while the other branch continues north along the Columbia River Valley. The topography allows southerly flow to be channeled from the smelter up the valley to the fork and then to the north and the northwest.

Terrain in this region is complex. Elevations vary from 200 meters (m) elevation mean sea level (MSL) in the vicinity of the smelter to 2500 m elevation at some peaks within the Alpine Lakes Wilderness (see Figure 6).

Alcoa Wenatchee Works initially followed the Washington-Oregon-Idaho BART Modeling Protocol and used 4-km meteorology to model the impacts from the aluminum smelter on nearby Class I Areas. However, close examination of the surface wind fields (for example, Figure 2) showed numerous locations where the modeled wind directions (indicated by the blue wind barb in the lower left corner of the 4-km grids) did not reflect the effects of the topography. Figure 3 shows a portion of Figure 2 in greater detail. It can be seen that the 4-km wind field attempts to cut across the terrain and fails to model the down-slope, down-valley flow normally observed early in the morning.

Alcoa Wenatchee Works believed that the apparent errors in the wind field were due to unresolved features of the complex terrain. Figure 4 shows terrain corresponding to a 4-km grid spacing. Alcoa Wenatchee Works proposed doing additional modeling at a higher grid resolution to improve the wind field for BART exemption modeling.

Ecology, through its membership in the Northwest Regional Modeling Center, has over a decade of daily experience with mesoscale meteorological models with grid spacing ranging from 36-km down to 1.3- km and occasionally in special studies down to 0.44-km. Ecology staff have seen the improvement in model performance that comes with refined grids and understand the conditions that require the smallest grid spacing.

Based on accumulated experience, Ecology was inclined to entertain a proposal to model with a finer grid. The characteristic scale of the terrain affecting transport of emissions from the Alcoa Wenatchee Works smelter to the Alpine Lakes Wilderness is on the same order as that

[1] The Washington-Oregon-Idaho Modeling Protocol may be found in Appendix H.

encountered in the Columbia River Gorge. Additionally, like the Columbia River Gorge the maximum impact occurs during the winter. Modeling wintertime flow through the Columbia River Gorge required the smallest grid spacing of 0.44 km to correctly characterize the flow[2].

After finding numerous references to analyses with CALPUFF using similar grid spacing in equally complex terrain between 1999 and 2007 and finding no mention of any lower limit to the acceptable meteorological grid spacing[3], Ecology concurred with Alcoa Wenatchee Works' proposal and notified the affected Federal Land Managers (FLMs). The horizontal grid spacing of the fine grid CALMET/CALPUFF modeling domain was 0.5-km. The domain covered an area of 209-km by 143-km (Figure 4). The domain includes the Alcoa Wenatchee Works, the Alpine Lakes Wilderness, and at least a 50-km buffer zone in each direction from the aluminum smelter and this Class I Area.

The revised BART exemption modeling followed the Washington-Oregon-Idaho BART modeling protocol except for a finer grid spacing of 0.5-km in the meteorological pre-processor and the use of CALPUFF version 5.8. EPA approved CALPUFF version 5.8 as a replacement for version 6.112 on June 28, 2007. The modeling used the same 3 years of 12-km mesoscale model wind fields as specified by the protocol.

The two years, 2007 and 2008, saw numerous changes in CALPUFF as one version after another became accepted as a guideline model only to be replaced by another. At the time Ecology made our decision to accept the 0.5-km grid modeling there were two model versions used for regulatory analyses: Version 5.8 for permitting (the Guideline model) and Version 6.112, accepted for BART analyses. Each analysis approved by Ecology was conducted according to the guideline or protocol in effect at the time.

Figures 2 and 3 compare the wind field computed at the 4 kilometer spacing with the wind field computed at the 0.5-km spacing. A measure of the frequency of misdiagnosed wind directions is depicted in Figure 2. The figure shows that ten of the 70 points on the 4-km grid shown in the figure had wind directions that failed to conform to the topography. These ten points are correctly modeled at the 0.5-km spacing.

Figure 3 is an enlargement of the area of Figure 2 outlined by a black box. Figure 3 shows in greater detail that the 4-km spacing produces a defective wind field that ignores the influence of the terrain or produces convergence on the slope of the valleys rather than at the bottom. The former is illustrated by the 4-km grid indicated by a blue barb inside a black box on the right side of the figure. The latter can be seen in two 4-km grids in the center of the figure. The 0.5-km wind field seems to accurately reflect the influence of topographic features.

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[2] Sharp, J and C Mass, The Mesoscale Meteorology of the Columbia River Gorge, Ninth Conference on Mesoscale Processes, 2001.

[3] Chang, et al, 2003 used 0.25 km. State and Federal agencies and regional planning organizations have used the following grid spacing: Colorado - 0.5 km, VISTAS – 1 km, Georgia -1.5 km, EPA - 0.4 km, and California - 0.1 to 0.5 km.

A vertical cross section of the terrain elevation along the east-west line in Figure 5 is shown in Figure 6. The terrain elevation is shown for 4 different resolutions corresponding to grid spacings of 12, 4, 0.5, and 0.1-km. The 12-km grid spacing corresponds to that of the mesoscale model used for the input meteorological wind fields, the 4-km terrain corresponds to the CALMET grid used in the initial runs, and the 0.5-km terrain was used in the final runs. Terrain at the high resolution 0.1 km grid spacing is provided for comparison.

The cross section at 4-km (plotted in cyan) smoothes out the peaks and the valleys drastically. The highest elevation of 4-km terrain is only 1820 m, well below the maximum of 2340 m for 0.5 km terrain (plotted in magenta). Many ridges and valleys are not resolved at 4-km resolution. The effects of smoothing are even more pronounced at the 12-km spacing (plotted in red).

The similarity of the 0.5-km and 0.1-km profiles confirms that the 0.5-km spacing adequately represents the terrain for modeling purposes.

Figure 3 clearly demonstrates that the 0.5-km resolved terrain provides a much better representation of terrain features and the wind field than does the 4-km resolution. Figures 2 and 3 show that the finer resolution modeling provides a much more detailed spatial pattern in the winds which conforms more accurately to the terrain when compared with the wind fields from the lower resolution runs. It is clear from these plots that the lower resolution runs will miss much of the terrain channeling within the modeling domain. More importantly, the failure of the 4-km grid to accurately represent peaks will allow air to flow unimpeded through regions that would otherwise deflect it.

The Environmental Protection Agency (EPA) has commented on the use of finer grid spacing in BART exemption modeling for the Otter Tail Power generating facility in Big Stone, SD[4]. The Clearinghouse memo set forth two components that an argument must address to run the CALPUFF meteorological pre-processor at a smaller grid spacing than the input meteorological wind fields:

(1) The resolution of the mesoscale model is insufficient to correctly characterize the transport of emissions between their source and the receptors of concern.
(2) The diagnostic wind model, CALMET, can enhance the mesoscale model data sufficiently to adequately replicate the key meteorological features governing the transport of emissions between their source and the receptors of concern.

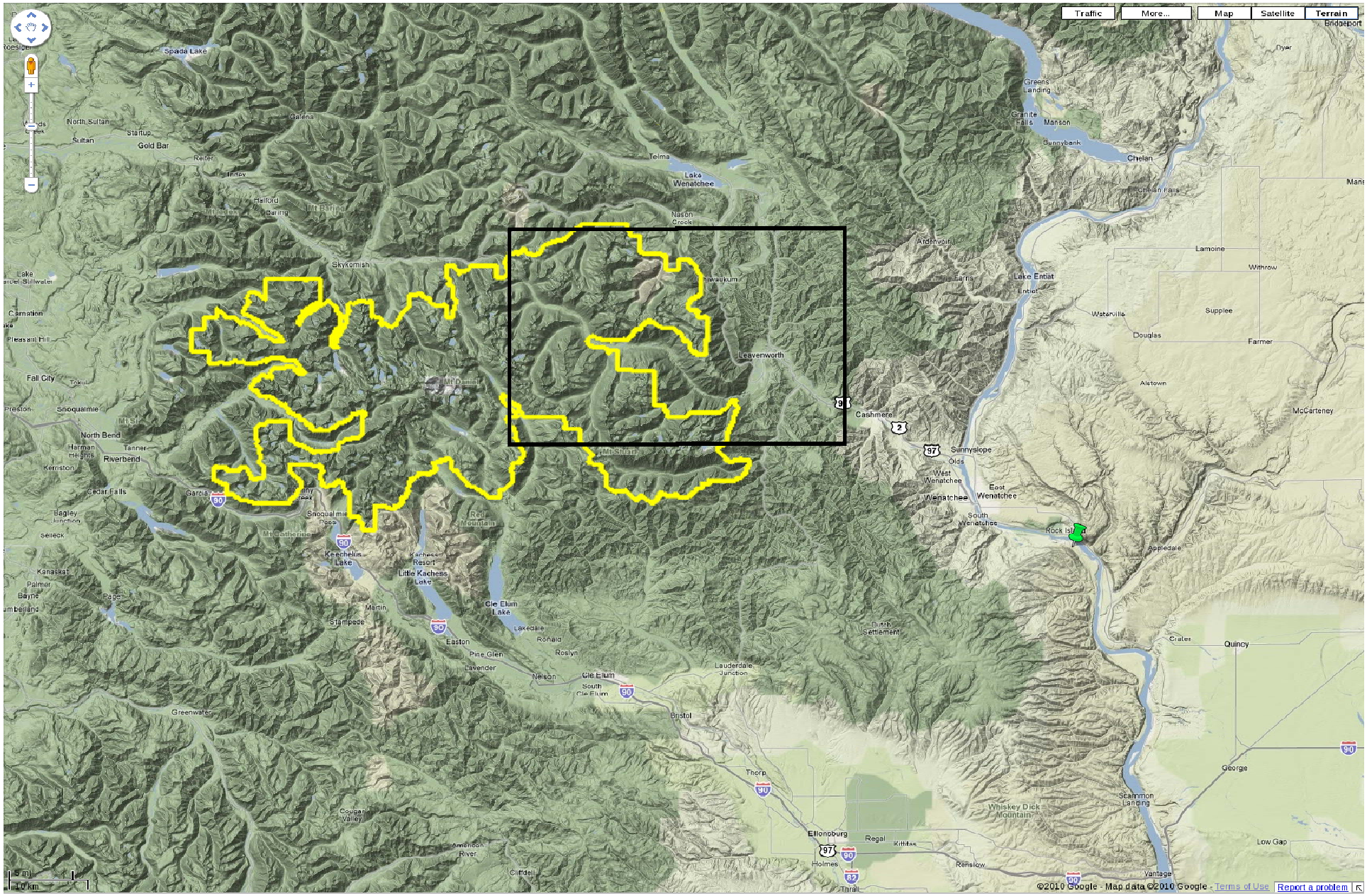
The first has been addressed above. The 4-km wind field, produced to meet the Washington-Oregon-Idaho Modeling Protocol, was strongly influenced by the input meteorological wind fields and has been shown to have a significant fraction of misaligned wind directions. The terrain analysis shown in Figure 6 satisfies the implied requirement of demonstrable terrain complexity stated in the Model Clearinghouse review of May 15, 2009.

[4] EPA, Model Clearinghouse Review of CALPUFF Modeling Protocol for BART, Memorandum from Tyler Fox, EPA-OAQPS, Research Triangle Park, NC, May 15, 2009.

The second is more difficult to satisfy directly in this analysis. There are no observations at sites along the path between the Alcoa Wenatchee Works and the Alpine Lakes Wilderness. Additionally, there were errors in the observations at Pangborn field in Wenatchee. Therefore there is no direct way to assess the improvement in the wind field by using the finer grid. An indirect argument must be made by combining experience with close scrutiny of the wind fields computed at the 0.5-km grid spacing. Figure 3 seems to indicate that the wind field computed on the 0.5-km grid responds to the topography in a reasonable manner.

Comparing the results of the 0.5-km modeling with the 4-km modeling shows that the finer grid spacing did not produce large changes in the magnitude or timing of the highest impacts (Figure 7). Figure 8 does show an important difference in the spatial location of impacts between the 4-km grid and the finer grid. Impacts occur at the eastern and southern boundaries of Alpine Lakes Wilderness during the winter for both the 4-km and 0.5-km grid spacings. Impacts occur at the western boundary, which is west of the Cascade Crest, only at the 4-km grid spacing. The spatial variation and differences in magnitude can be attributed to the different effect that the more highly resolved terrain has on the trajectories of emissions from the Alcoa Wenatchee Works aluminum smelter. Because the maximum impacts computed using the 0.5-km grid continue to occur during winter, we may conclude that the predicted maximum impacts will occur in similar meteorological conditions at both grid scales.

In summary, Ecology's decision to accept Alcoa Wenatchee Works' use of 0.5-km grid resolution and CALPUFF 5.8 for BART exemption modeling of the Alcoa Wenatchee Works facility was based on an analysis showing that the finer grid resolution provided a more accurate result, given the complex terrain surrounding the Alcoa Wenatchee Works aluminum smelter.


Traffic
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Map
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Terrain
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Startup
Sultan
Gold Bar
Reiter
Halford
Baring
Mt Baring
Skykomish
Telma
Lake Wenatchee
Nason Creek
Leavenworth
Mt Daniel
Mt Stuart
Lake Stillwater
Carnation
Pleasant Hill
Fall City
Snoqualmie
Mt Si
North Bend
Harman Heights
Tanner
Riverbend
Kerriston
Cedar Falls
Garcia
Snoqualmie Pass
Mt Catherine
Keechelus Lake
Kachess Resort
Little Kachess Lake
Red Mountain
Cle Elum Lake
Lakedale
Roslyn
Easton
Martin
Stampede
Pine Glen
Lavender
Nelson
Cle Elum
South Cle Elum
Bristol
Lauderdale Junction
Greenwater
Cougar Valley
American River
Cliffdell
Thorp
Ellensburg
Regal
Kittitas
Holmes
Renslow
Thrall
Whiskey Dick Mountain
Scammon Landing
Vantage
Low Gap
Quincy
Crater
Georgie
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Rock Island
South Wenatchee
Wenatchee
East Wenatchee
West Wenatchee
Olds
Sunnyslope
Cashmere
Ardenvoir
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Dutch Settlement
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Figure I-1 Terrain near the Alcoa Wenatchee Works. The green pushpin marks the location of the Alcoa Wenatchee Works aluminum smelter in the Columbia River Valley. The Columbia River flows from north to south along the east side of the Cascade Mountains. The Valley branches upstream from the smelter at Olds with one branch heading northwest to the Alpine Lakes Wilderness, which is outlined in yellow. The black rectangle outlines the area shown in Figure 2. North is up on all maps in this appendix.

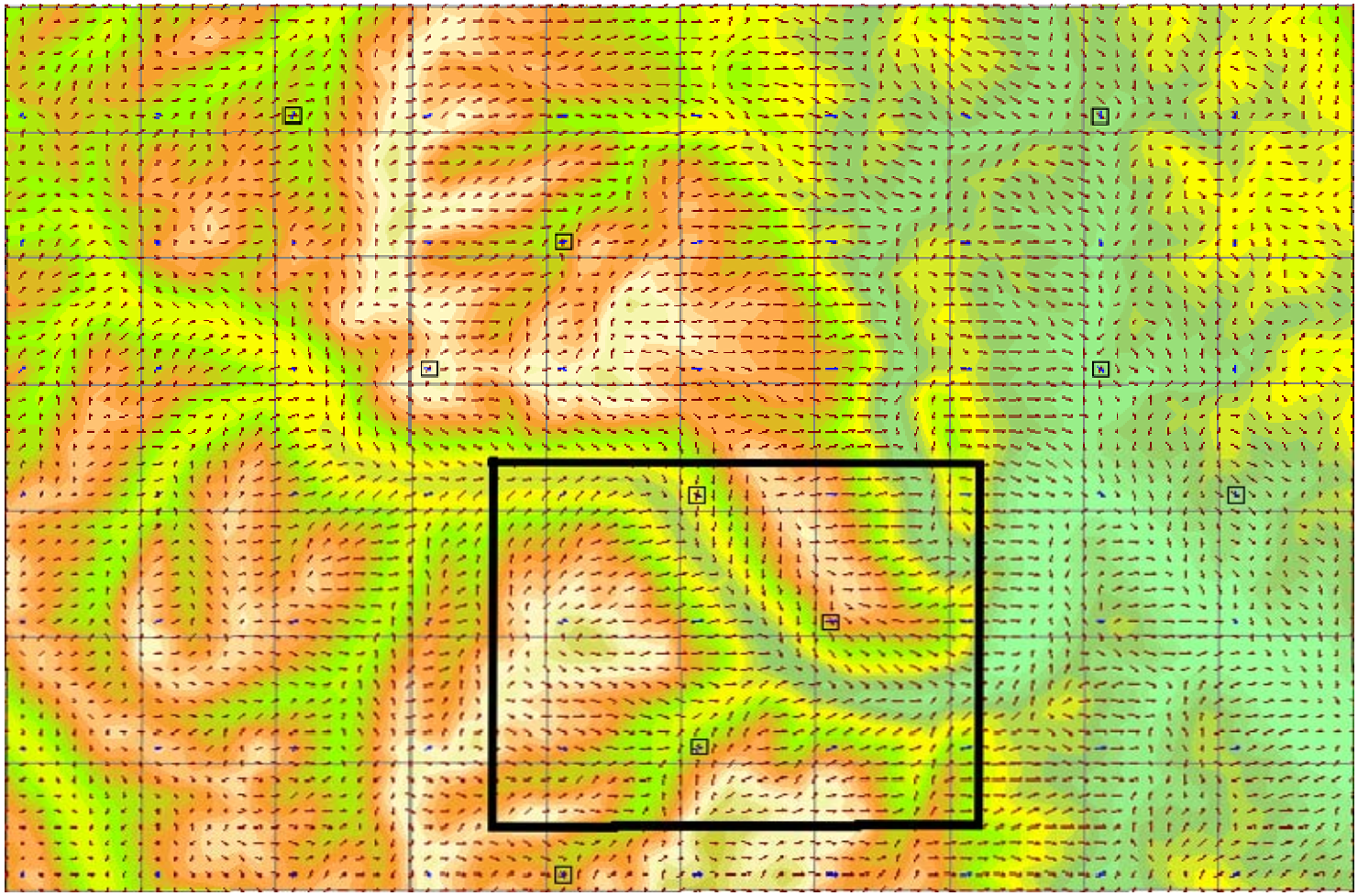

Figure I-2 Sample wind field (5 am on Jan 5, 2003. The ten small black squares show points where there is a significant difference in direction between the 4-km (blue barbs) and 0.5-km (red barbs) wind fields. The large black rectangle outlines the area shown in greater detail in Figure 3.

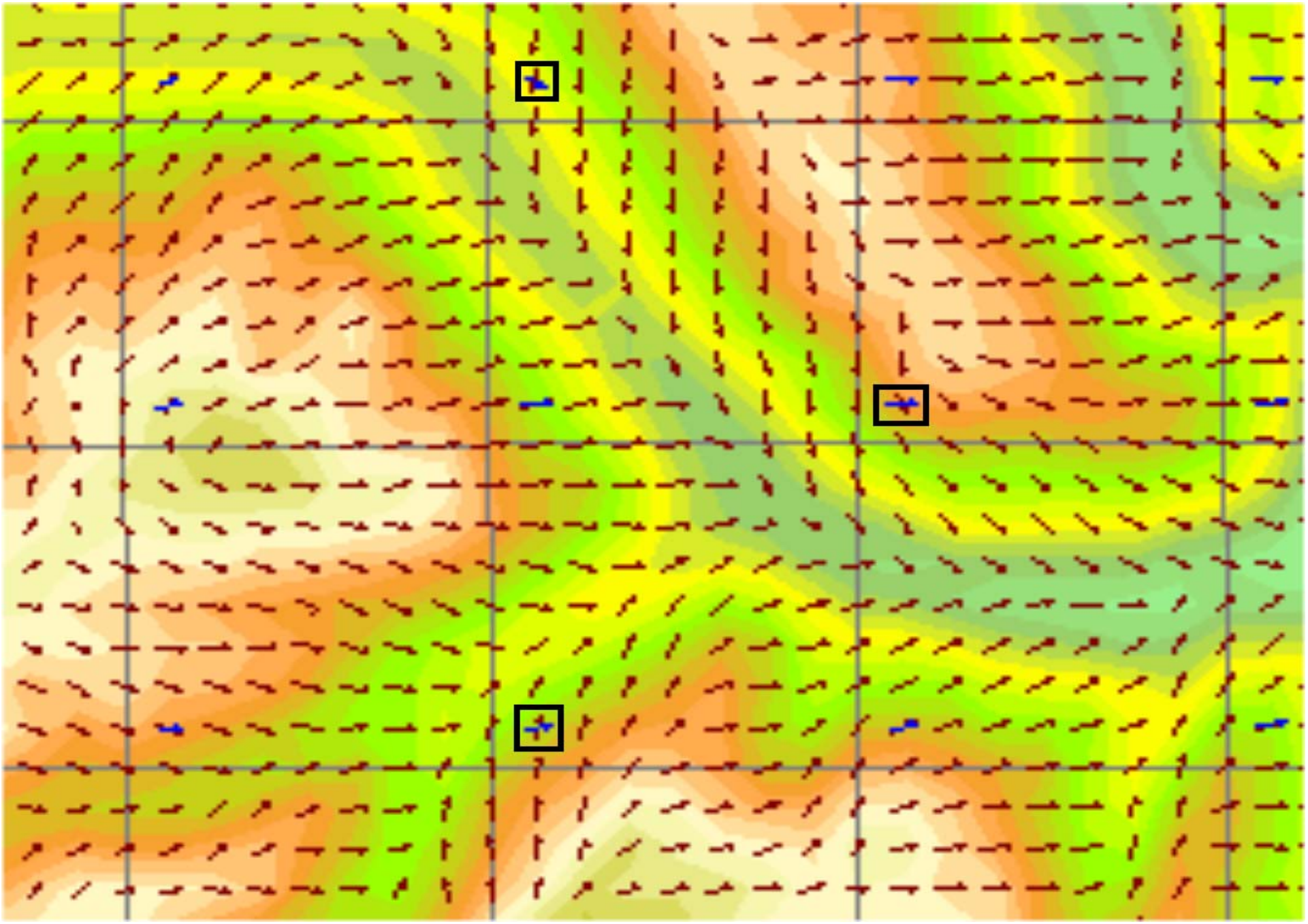

Figure I-3 Close-up of 0.5-km terrain with 4-km (blue barbs at lower left of each 4-km grid square) and 0.5- km (red barbs) wind fields. Small black squares are drawn to emphasize where there is a significant difference in the wind fields.

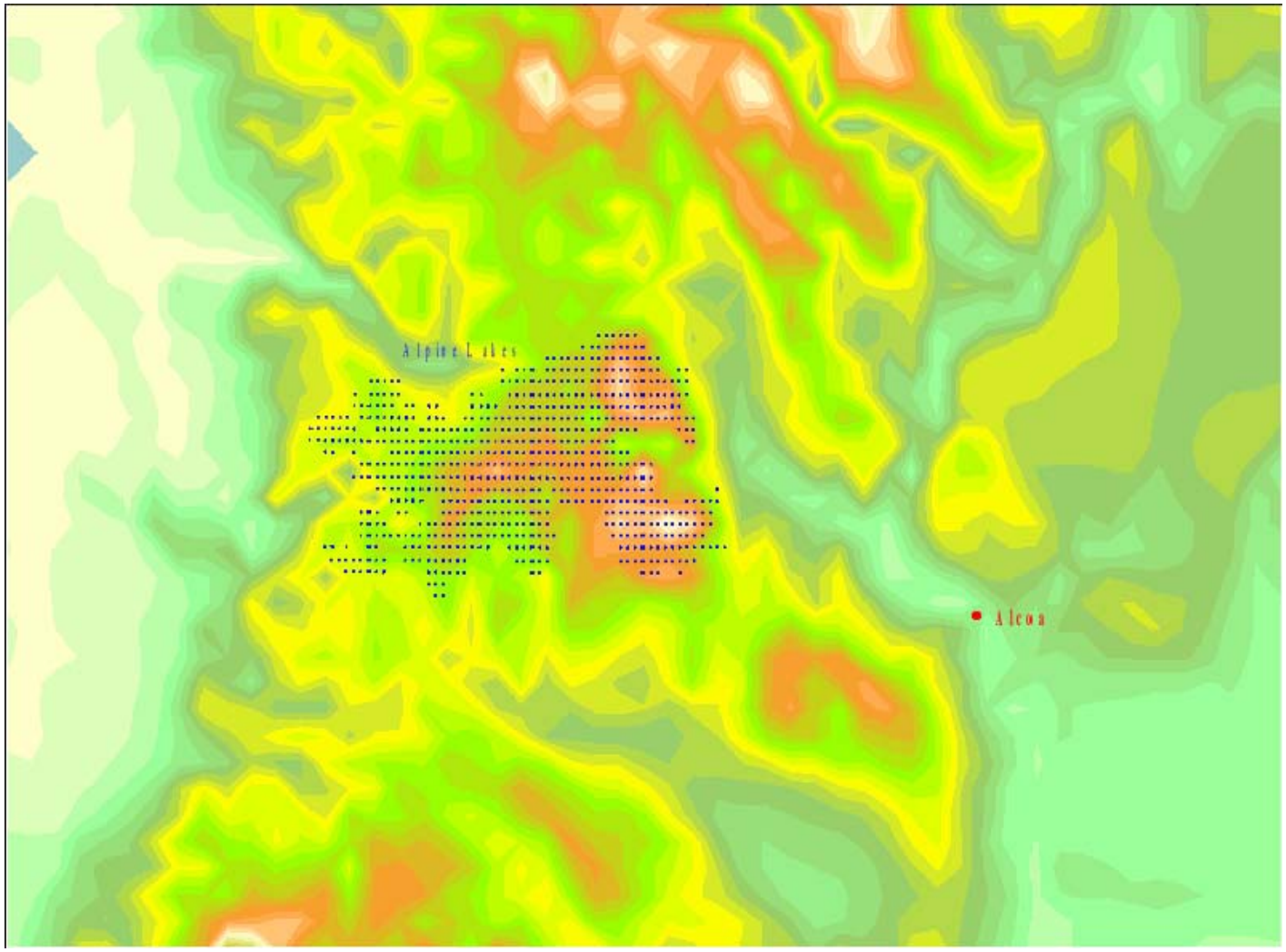
Alpine Lakes
Alcoa

Figure I-4 Terrain at 4-km resolution with FLM-defined receptors in the Alpine Lakes Wilderness Class I Area. The location of the Alcoa Wenatchee Works aluminum smelter is marked by the red dot. Note the relative softness of the terrain compared with Figure 1. Many features that affect the transport of emissions into the Class I Area have been smoothed and are missing.

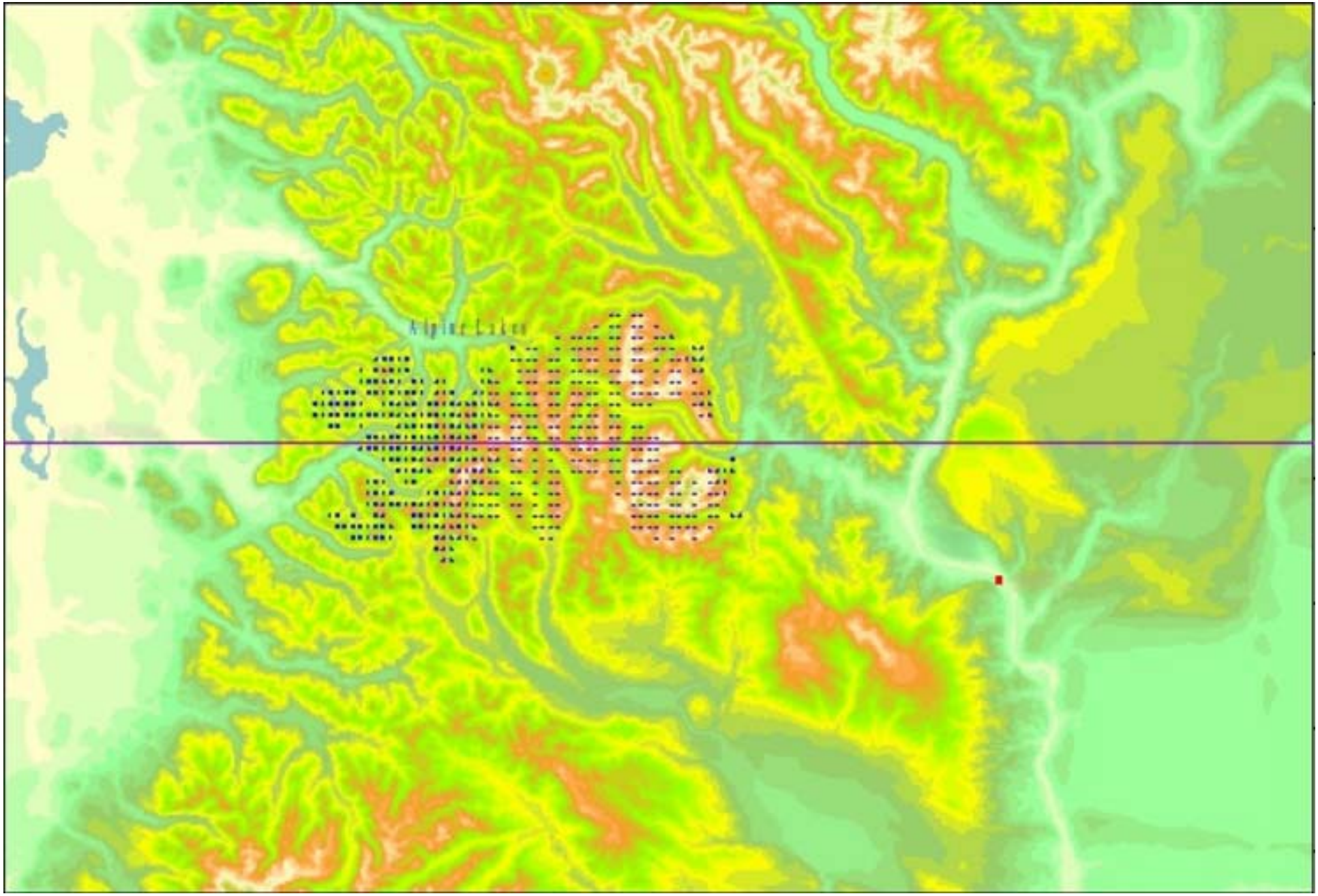
Alpine Lakes

Figure I-5 Terrain at 0.5-km resolution with FLM-defined receptors in Alpine Lakes Wilderness Class I Area. The location of the Alcoa Wenatchee Works aluminum smelter is marked by the red dot. Note the better definition of terrain feature compared with Figure 4, especially valleys and side channels, which are important in defining the transport of emissions into the Class I Area.

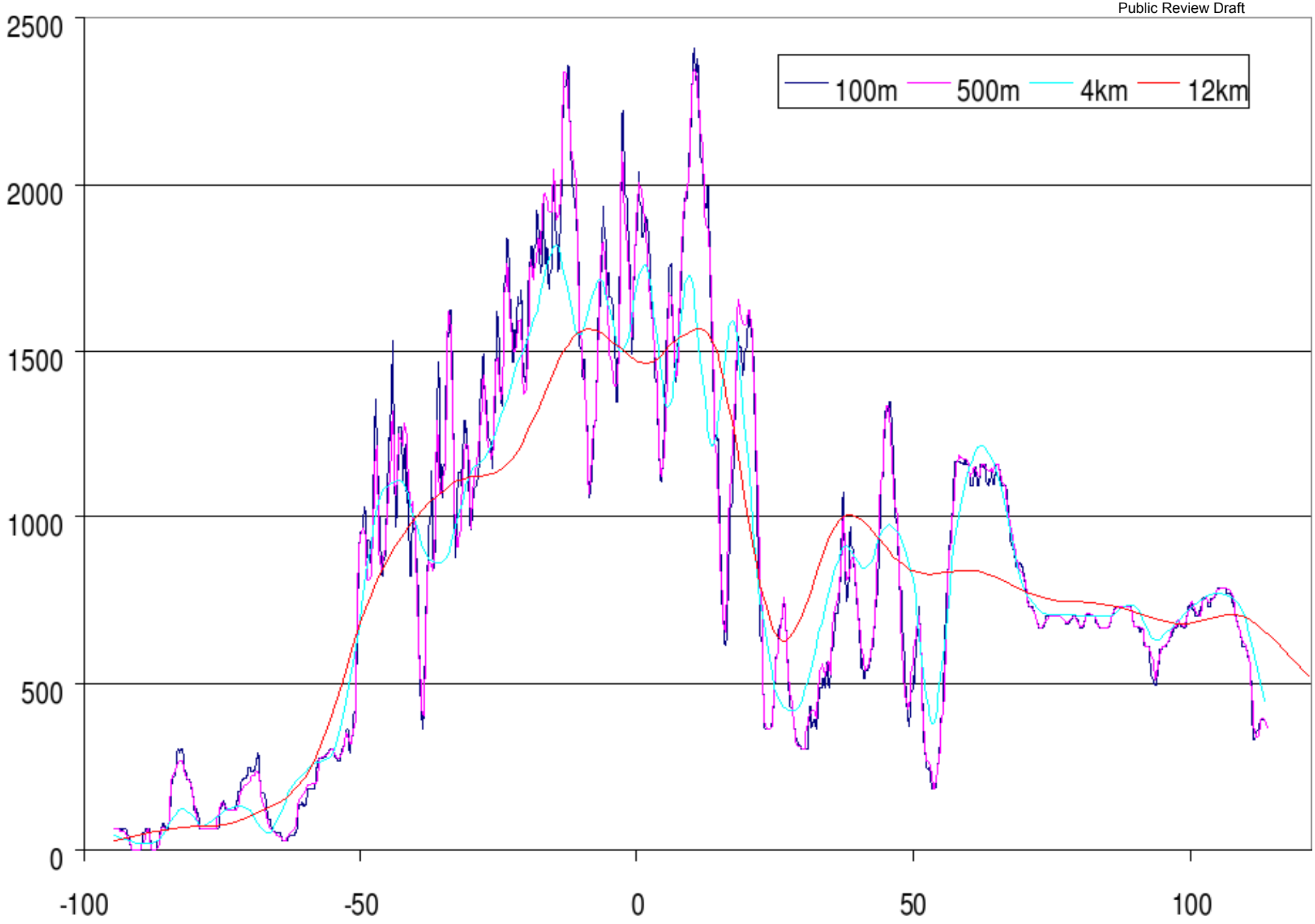
2500
2000
1500
1000
500
0
-100
-50
0
50
100
100m
500m
4km
12km

Figure I-6 Terrain profile at four different resolutions along the east-west line in Figure 5. Elevations are in meters and distances are in kilometers. The horizontal scale is approximately the same as Figure 5.

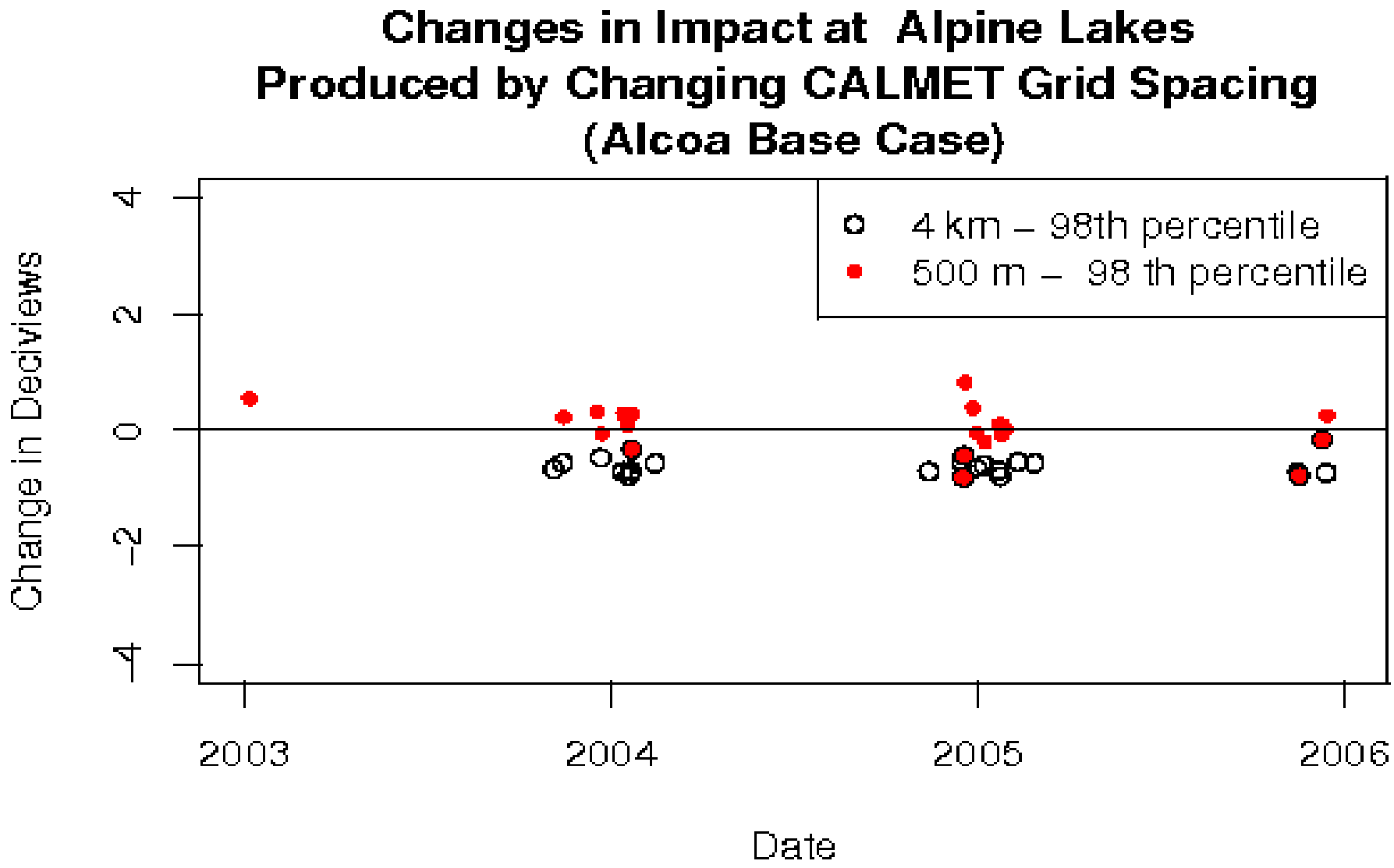

Figure I-7 Dates of 98th percentile impacts at 4-km and 0.5-km grid spacings. Note that the highest impacts are in the winter regardless of the grid spacing used. The changes are computed as the difference between the highest impact on a specific day at each grid spacing. For

example, taking the isolated red point in early 2003, the 0.5-km grid spacing run produced a slightly higher maximum impact to the Alpine Lakes Wilderness Area on one of the 22 days that make up the highest two percent of impacts than was computed using the 4-km spacing. It can also be seen that computed impacts using the 4-km spacing during the first part of 2003 were not in the highest two percent. Changes of less than 1 deciview are generally not noticeable.

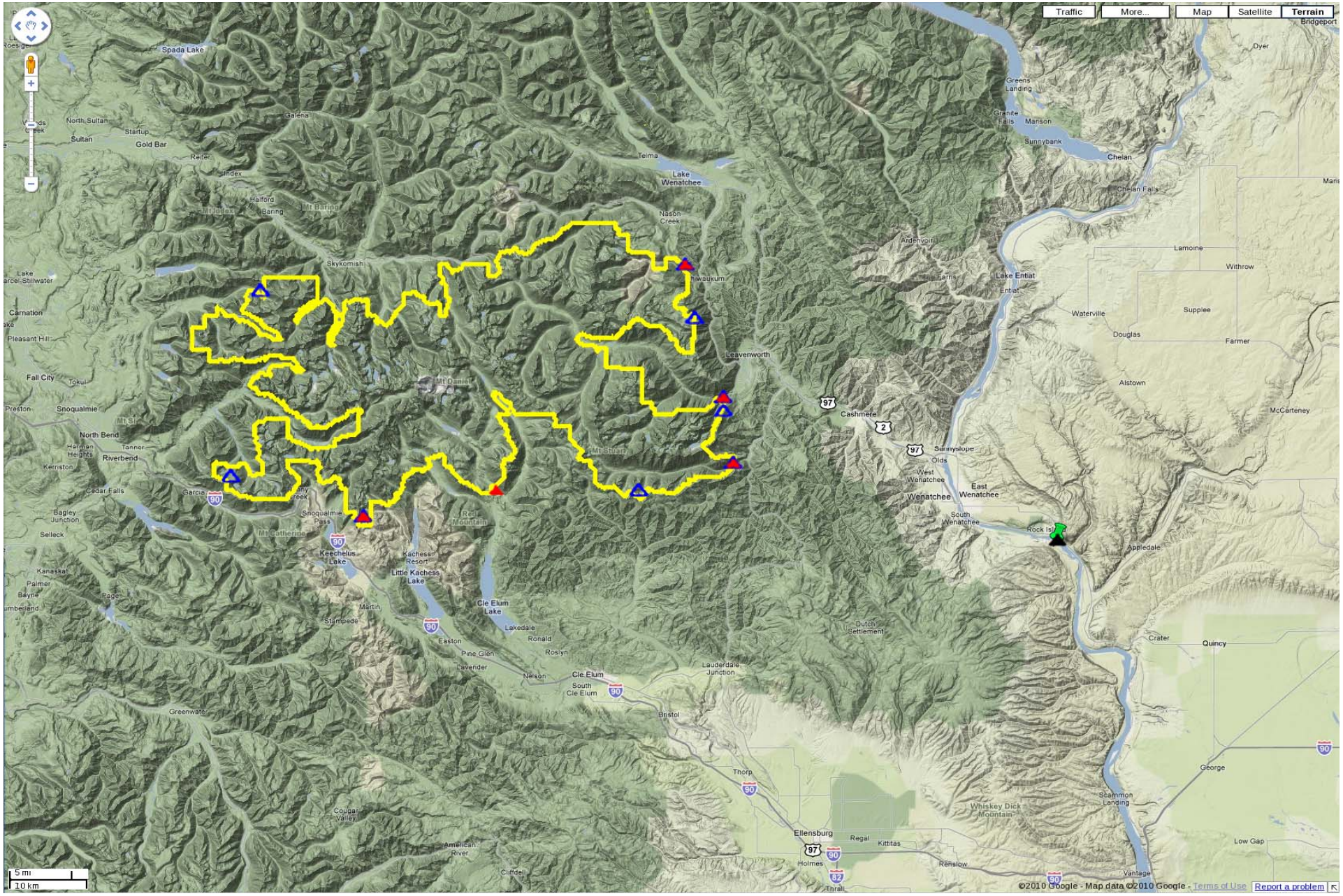

Figure I-8 Locations of the impacts in the highest two percent. The open purple symbols show locations from the 4-km run and the solid red symbols are locations from the 0.5-km run. The green pushpin shows the location of the Alcoa Wenatchee Works smelter. The Alpine

Lakes Wilderness is outlined in yellow. Note that in addition to the impacted locations along the east and south wilderness boundary for both grid spacings, the 4-km run has high impacts along the west wilderness boundary, which is west of the crest of the Cascade Mountains.