The following text provides documentaion for the methodology utilized by the spreadsheet "sample.wk4" and "sample.xls" to calculate monthly average emission factors for unpaved roads section. The below text provides more detail than is presented in the text on page 13.2.2.5 of AP-42 that discusses the use of default vehicle weights, silt contents and moisture content.

The effect of routine watering to control emissions from unpaved roads is discussed in Section 13.2.2.3 of AP-42. However, all roads are subject to some natural mitigation because of rainfall and other precipitation. Two methods are presented in AP-42 Sectiona 13.2.2.2 that can be used to accommodate the natural mitigation of emissions. The method presented in its entirety, requires information on the number of days that have a measureable amount of rain. I n the absence of detailed meterological information, this method can be used to accomodate the natural mitigation of emissions. The text in AP-42 explains that the basic emission factor equation can be extrapolated to annual average uncontrolled conditions (but including natural mitigation) under the simplifying assumption that the number of days with measurable (more than 0.254 mm [0.01 inch]) have a direct affect on the average road surface moisture content. The equation presented in AP-42 is:

$$E_{ext} = k\,(s/12)^a\,(W/3)^b\,(M_{dry}/0.2)^c\,[(365-p)/365]$$

where s, W, k, a, b, and c are given earlier in the AP-42 section and

E_{ext} = annual size specific emission factor extrapolated for natural mitigation
M_{dry} = surface material moisture content under dry conditions, %
p = number of days with at least 0.254 mm (0.01 in) precipitation per year

The application of this method is very simple but provides for limited spatial and temporal resolution. Prior to the development of an emission factor equation which included the surface moisture content as an independent variable, the number of days with greater than 0.01 inches of rain was recommended as an adjustment in an attempt to arrive at an annual average effect of the moisture dynamics of the road surface material. Although no detailed validation of this adjustment was made, it produced results that were believed to be more valid. However imperfect this adjustment was, it was directionally correct in that increased number of rain days probably results in a higher annual average surface moisture content and lowered emissions.

The second method presented is calculationally more complex and requires more detailed meterological information. It is believed that the second method results in emission factors with improved temporal and spatial resolution. This more complex method recognizes that the moisture content of the surface material of an unpaved road is affected by a variety of meteorological and physical parameters. For urban roads, rain is the primary meteorological event which adds moisture to the road surface. The frequency, duration and quantity of rain are important aspects which determine the long term average moisture content. Water which condenses in the air and is deposited on the road surface is of less significance in determining the long term moisture content. Deeper layers of the road provide a reservoir of moisture that can slowly transpire to the surface over long periods of time to temper the loss of moisture due to evaporation. The primary meteorological parameters which affect the evaporation of moisture from the road surface include solar radiation, temperature, dew point and wind speed. It is believed that the “Class A Pan Evaporation” is a reasonable indicator of the long term combined effects on an unpaved road of these atmospheric parameters. Some physical parameters which affect the moisture content of the surface material include the amount and size distribution of the loose surface material and vehicle traffic on the road. The amount and size distribution of the loose surface material would affect the maximum amount of water that the surface material is capable of holding. Vehicle traffic enhances the evaporation of moisture from the road surface due to the increase in surface air movement. The existence of trees and other natural and man made formations may affect the moisture balance of the road surface material. As with the previous methodology which was used to accommodate differences in meteorology, this more complex method has not been validated. To estimate the surface moisture content of urban roads the following methodology can be used.

Measurable rain events add water to the road surface material up to the maximum retention ability of the loose surface material. The available existing data indicate that the loose surface material is only capable of holding about 20% moisture. However, it is plausible that higher values may occur in rare instances. For road surface material with a density of 90 lb/ft^3 a rain of 0.025 inches would saturate ¼ inch (0.635 cm) of dry road surface material.

Periods of very high humidity that cause water to condense from the air and deposit on the surface of the road result in a minor increase in the moisture content of the road surface material. It is assumed that each hour of 100% relative humidity without measured rain is equivalent to a rain of 0.01 inches. As with measurable rain events, water in excess of the maximum retention ability will drain off the surface material.

It is assumed that water will evaporate from the road surface material in proportion to 75% of the monthly Class A Pan evaporation and the amount of traffic over the road. The following equation describes the hourly evaporation:

$$Q_{rs} = Q_{rsp} - (0.75 * 1.37 \times 10^{-3} * P * V_h)$$

where:

Q_{rs} = The average equivalent depth of water (inches) contained in the road surface material during the hour.

Q_{rsp} = The average equivalent depth of water (inches) contained in the road surface material during the previous hour.

P = The Class A Pan evaporation constant for the month.

V_h = The average hourly vehicle count per traffic lane.

In addition to being a critical parameter governing the moisture content of the road surface material, rain can act like a wet scrubber to reduce the emissions from the road. The effectiveness of rain in controlling the emissions from the road depends on the rain intensity. Rains of 0.01 inches per hour probably do not effect any control on emissions. However, rains of

1 inch per hour may provide a very high degree of control. For the purposes of National emissions estimates, it is assumed that 0.1 inches per hour of rain will reduce emissions by 80%.

Another meteorological event that is believed to affect emissions from unpaved roads is snow. Snow cover on the unpaved road will prevent contact between vehicle wheels and the road surface. It is unlikely that emissions from the road would occur when there is no contact and while there is a barrier between the road surface and the turbulent air movement created by passing vehicle. It is assumed that during the period that vehicles drive on snow, road surface emissions do not occur. Only tailpipe emissions, tire wear and brake wear occur. For the purposes of National emissions estimates, it is assumed that unpaved roads are not plowed to remove snow and that a 6 inch snow depth will result in sufficient snow depth on unpaved roads to prevent contact between vehicle wheels and the road surface.

To facilitate the calculation of the average monthly emission factor for a location, a spreadsheet is available which calculates the above dynamic event. Information which is required for calculating the average monthly emission factors includes hourly rain quantities, hourly humidity percents, hourly snow depths, average hourly traffic counts and monthly Class A Pan evaporation data. This information can be obtained from the National Climatic Data Center (NCDC) in Asheville, NC (URLhttp://www.nndc.noaa.gov/phase3/productaccm.htm). Examples of the climatological data available from NCDC are available with the file containing the spreadsheet program.