2.0 NATURE OF THE OZONE AIR QUALITY PROBLEM IN THE NORTHEAST – THE CONCEPTUAL MODEL

In its Phase 2 ozone implementation rule,[1] the USEPA required states to include in their SIPs a conceptual description of the pollution problem in their nonattainment areas. This section outlines the basics of the ozone problem in the Northeastern United States. As discussed in greater detail in Appendix A, the ozone problem throughout this region is a product of both locally generated emissions, and those emissions released upwind of an area and transported over time to the area of concern. By understanding how ozone is formed and transported throughout the area, state air agencies have a foundation for how to effectively address the problem in the allotted timeframe.

The Ozone Transport Region (OTR) of the eastern United States covers a large area that is home to over 62 million people living in Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and northern Virginia. Each summer, the people who live within the Ozone Transport Region are subject to episodes of poor air quality resulting from ozone pollution that affects much of the region. During severe ozone events, the scale of the problem can extend beyond the Ozone Transport Region's borders and include over 200,000 square miles across the eastern United States. Contributing to the problem are local sources of air pollution as well as air pollution transported hundreds of miles from distant sources in and outside the Ozone Transport Region.

Since the late 1970s, a wealth of information has been collected concerning the regional nature of the Ozone Transport Region's ground-level ozone air quality problem. Scientific studies have uncovered a rich complexity in the interaction of meteorology and topography with ozone formation and transport. The evolution of severe ozone episodes in the eastern United States often begins with the movement of a large high pressure area from the Midwest to the middle or southern Atlantic states, where it assimilates into and becomes an extension of the Atlantic (Bermuda) high pressure system. During its movement east, the air mass accumulates air pollutants emitted by large coal-fired power plants and other sources located outside the Ozone Transport Region. As the air mass passes over the eastern United States, sources within the Ozone Transport Region contribute to the air pollution burden. These expansive weather systems favor the formation of ozone by creating a vast area of clear skies and high temperatures. These two prerequisites for abundant ozone formation are further compounded by a circulation pattern favorable for pollution transport over large distances. In the worst cases, the high pressure systems stall over the eastern United States for days, creating ozone episodes of strong intensity and long duration.

One transport mechanism that has fairly recently come to light and can play a key role in moving pollution long distances is the nocturnal low level jet stream. The jet is a regional scale phenomenon of higher wind speeds that often forms during ozone events a few hundred meters above the ground just above the stable nocturnal boundary layer. It can convey air pollution several hundreds of miles overnight from the southwest to the

[1] 70 Fed. Reg., 71612-71705 (November 29, 2005).

northeast, directly in line with the major population centers of the Northeast Corridor stretching from Washington, D.C. to Boston, Massachusetts. The nocturnal low level jet extends the entire length of the corridor from Virginia to Maine, and has been observed as far south as Georgia. It can thus be a transport mechanism for bringing ozone and other air pollutants into the Ozone Transport Region from outside the region, as well as move locally formed air pollution from one part of the Ozone Transport Region to another. Other transport mechanisms occur over smaller scales. These include land, sea, mountain, and valley breezes that can selectively affect relatively local areas. They play a vital role in drawing ozone-laden air into some areas, such as coastal Maine, that are far removed from major emission source regions.

With the knowledge of the different transport scales into and within the Ozone Transport Region, a conceptual picture of bad ozone days emerges. After sunset, the ground cools faster than the air above it, creating a nocturnal temperature inversion.[2] This stable boundary layer extends from the ground to only a few hundred meters in altitude. Above this layer, a nocturnal low level jet can form with higher velocity winds relative to the surrounding air. It forms from the fairly abrupt removal of frictional forces induced by the ground that would otherwise slow the wind. Absent this friction, winds at this height are free to accelerate, forming the nocturnal low level jet. Ozone above the stable nocturnal inversion layer is likewise cut off from the ground, and thus it is not subject to removal on surfaces or chemical destruction from low level emissions. Ozone in high concentrations can be entrained in the nocturnal low level jet and transported several hundred kilometers downwind overnight. The next morning as the sun heats the Earth's surface, the nocturnal boundary layer begins to break up, and the ozone transported overnight mixes down to the surface where concentrations rise rapidly, partly from mixing and partly from ozone generated locally. By the afternoon, abundant sunshine combined with warm temperatures promotes additional photochemical production of ozone from local emissions. As a result, ozone concentrations reach their maximum levels through the combined effects of local and transported pollution. Ozone moving over water is, like ozone aloft, isolated from destructive forces. When ozone gets transported into coastal regions by bay, lake, and sea breezes arising from afternoon temperature contrasts between the land and water, it can arrive highly concentrated.

During severe ozone episodes associated with high pressure systems, these multiple transport features are embedded within a large ozone reservoir arriving from source regions to the south and west of the Ozone Transport Region. Thus a severe ozone episode can contain elements of long range air pollution transport from outside the Ozone Transport Region, regional scale transport within the Ozone Transport Region from channeled flows in nocturnal low level jets, and local transport along coastal shores due to bay, lake, and sea breezes.

From this conceptual description of ozone formation and transport into and within the Ozone Transport Region, air quality planners need to develop an understanding of what it will take to remove high ozone concentrations from the air in the Ozone Transport Region. Weather is always changing, so every ozone episode is unique in its specific

[2] A temperature inversion is an increase in measured air temperature with height.

details. The relative influences of the transport pathways and local emissions vary by hour and day during the course of an ozone episode and between episodes. The smaller scale weather patterns that affect pollution accumulation and its transport underscore the importance of local (in-state) controls for emissions of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), the main precursors of ozone formation in the atmosphere. Larger synoptic scale weather patterns, and pollution patterns associated with them, support the need for NO_x controls across the broader eastern United States. Studies and characterizations of nocturnal low level jets also support the need for local and regional controls on NO_x and VOC sources as locally generated and transported pollution can both be entrained in nocturnal low level jets formed during nighttime hours. The presence of land, sea, mountain, and valley breezes indicate that there are unique aspects of pollution accumulation and transport that are area-specific and will warrant policy responses at the local and regional levels beyond a one-size-fits-all approach. The mix of emission controls is also important. Regional ozone formation is primarily due to NO_x, but VOCs are also important because they influence how efficiently ozone is produced by NO_x, particularly within urban centers. While reductions in anthropogenic VOCs will typically have less of an impact on the long-range transport of ozone, they can be effective in reducing ozone in urban areas where ozone production may be limited by the availability of VOCs. Therefore, a combination of localized VOC reductions in urban centers with additional NO_x reductions across a larger region will help to reduce ozone and precursors in nonattainment areas as well as downwind transport across the entire region.

The recognition that ozone in the eastern United States is a regional problem requiring a regional solution marks one of the greatest advances in air quality management in the United States. During the 1990s, air quality planners began developing and implementing coordinated regional and local control strategies for NO_x and VOC emissions that went beyond the previous emphasis on urban-only measures. These measures have resulted in significant improvements in air quality across the Ozone Transport Region. Measured NO_x emissions and ambient concentrations have dropped between 1997 and 2005, and the frequency and magnitude of ozone exceedances have declined within the Ozone Transport Region. To maintain the current momentum for improving air quality so that the Ozone Transport Region states can meet their 8-hour ozone attainment deadlines, there continues to be a need for more regional NO_x reductions coupled with appropriate local NO_x and VOC controls.