1. Introduction

1.1 Reason for study

As a result of concerns over visual air quality at Big Bend National Park, a preliminary regional visibility study was conducted in Texas and northern Mexico in September and October 1996. A brief overview of the study and consensus results are presented here. A more detailed description of the study and the reasons for conducting the preliminary study are contained in the report "Big Bend National Park Regional Visibility Preliminary Study" prepared by the Big Bend Air Quality Work Group for the USEPA, National Park Service, and the Mexican governmental agencies PROFEPA and SEMARNAP on January 7, 1999.

The primary objective of the study was to obtain information that would allow for the identification of possible source regions in both countries and source types responsible for visibility degradation at Big Bend National Park. The study was not intended or designed as an attribution study to quantify impacts of specific sources on Big Bend air quality. The study was intended to obtain information on pollutant gradients over a broad area of Texas and northeast Mexico to assist in the design of a future study to identify the causes of visibility impairment at Big Bend (Big Bend Air Quality Work Group, 1999). The study was conducted at 19 monitoring stations (10 in Texas, 9 in Mexico- see Figure 1-1) from September 9 through October 13, 1996. The sites sampled $PM_{2.5}$ at all sites and PM_{10} at Big Bend and Guadelupe Mountains national parks. The $PM_{2.5}$ filters were analyzed for chemical composition.

Figure 1-1. Map showing monitoring sites for preliminary visibility study.

It was noted that care should be taken in interpreting the results of the study due to its' limited duration and geographical coverage. Consensus was not reached by the work group on all issues. Key consensus results are paraphrased below:

- To the northeast of Big Bend are large sources of sulfur associated with selenium, likely from coal-fired power plants at distances that can exceed 700 km. These sources sometimes cause high concentrations of fine particulate and fine particulate sulfur through much of Texas, including Big Bend National Park.

- On some occasions with southerly flow, Mexican emissions appear to be associated with significant sulfur concentrations at Big Bend.

- During periods with southeasterly winds, emissions from both Mexico and the United States may contribute to $PM_{2.5}$ mass and fine particulate sulfur at Big Bend. Also, because of the lack of correlation between sulfur and selenium and vanadium, sources in addition to power plants are contributing to these concentrations.

- Transport from areas to the northwest of Big Bend is associated with relatively low concentrations of fine particulate mass and fine particulate sulfur.

- Relative humidity plays a large role in visibility impairment at Big Bend.

- Fine particulate sulfur plays a large role in visibility impairment at Big Bend and most of the particulate sulfur is in the form of sulfate.

The work group made the following recommendations:

1. A more extensive field study will be needed to quantify the impacts from specific sources to visibility impairment at Big Bend National Park.

2. The spatial domain of the study should be expanded, particularly to the northeast, the south, and into the Gulf of Mexico.

3. The design of the extensive study should be based on the findings from the final report of the preliminary regional study. The results of the preliminary study and the extensive study to follow should be analyzed in the context of historical measurements made at Big Bend National Park.

BRAVO is the more detailed study to follow the preliminary study. The United States and Mexico did not reach agreement on study design; as a result, BRAVO includes monitoring in the United States only. The monitoring program conducted for BRAVO is described in section 4.

1.2 Organizational Structure

Overall direction of the BRAVO study is the responsibility of the BRAVO steering committee. The steering committee has representatives of the United States Environmental Protection Agency (USEPA), the National Park Service (NPS), and the Texas Natural Resources Conservation Commission (TNRCC). A sub-committee of the steering committee is comprised of representatives of non-governmental organizations (NGOs), such as industry and environmental groups. While comments on BRAVO are welcome from all members of the public, the steering committee will actively solicit comments from the NGO committee regarding study plans, data analysis methods, and study results.

The technical sub-committee includes investigators that are collecting data or doing data analysis, including quality assurance. This sub-committee will provide a forum for presentation of technical analysis as well as scientific debate regarding the conclusions of various data analysis methods.

1.3 Goals

The primary goals of the Big Bend Regional Aerosol and Visibility Observational Study (BRAVO) are to understand the long-range, trans-boundary transport of visibility-reducing particles from regional sources in the U.S. and Mexico and to quantify the contributions of specific U.S. and Mexican source regions and source types responsible for poor visibility at Big Bend NP.

It is the goal of BRAVO to take advantage of the best and most successful aspects of previous visibility attribution studies. Previous air quality studies in the desert southwest (including SCENES, VIEW, VISTA, WRAQ, RESOLVE, WHITEX, and Project MOHAVE) and the U.S.-Mexico Preliminary Study provide a great deal of background information useful to the planning of this project.

Determining the contribution to BBNP haze implies a quantitative evaluation of intensity, spatial extent, frequency, and duration. The intensity of haze contributed by a source includes both an absolute physical measure of haze (e.g., contribution to the extinction coefficient) and its perceptibility (e.g. as displayed by computer image processing algorithms).

In addition to determining impacts from individual sources, simultaneous assessment of all the important regional sources of haze at BBNP is desirable. This would allow for the formulation of more effective emissions control strategies in both countries that would ultimately result in the improvement of air quality in BBNP and throughout the region.

Other goals that are relevant to the BRAVO Study include:

- Determination of the chemical constituents of fine particles responsible for regional hazes along the U.S.-Mexico border, inclusive of Big Bend;

- Determination of the effects of meteorology including moisture from the Gulf of Mexico on visibility-reducing particles.
- Evaluate and improve the accuracy of atmospheric models and source attribution methods through the use of atmospheric tracers and updated source emissions profiles.

2 Background

Visual air quality at a site depends largely upon the size, chemical composition, and concentration of atmospheric particles (aerosols). These aersosol properties are in turn dependent upon many factors, including: the relationship between the receptor site (e.g. Big Bend) and sources of pollutant emissions and the atmospheric transport and dispersion relating the source and receptor location, chemical transformation of emissions between source and receptor, (e.g. gas-to-particle conversion) wet or dry deposition, and relative humidity at the receptor.

Following a brief description of the Big Bend area will be a look at pollutant emissions for sulfur dioxide. The seasonally varying transport patterns affecting Big Bend National Park will then be examined, followed by a summary of light extinction and aerosol chemical component data for Big Bend. Finally, conditional probability plots will be shown indicating the probability that light extinction or chemical species were high at Big Bend when air passed over each geographic area en route to Big Bend.

2.1 Setting

In a remote area of southwestern Texas, where the Rio Grande makes a large U-turn along the US-Mexico border, lies an area known as the "Big Bend Country." Within this expanse lies BBNP, Texas,--a 324,247 hectare (1,252 square miles) reserve--established as a national park in 1944 and designated as a Biosphere Reserve in 1976. (Figure 2-1). Big Bend is a land of contrasts: the Rio Grande--portions of which have been designated as a Wild and Scenic River; desert--BBNP is 97 percent Chihuahuan Desert; and mountains--the Chisos Mountains--which tower 2400 meters (7800 feet) above the desert sea and the Sierra del Carmen across the river in Mexico. Along the Rio Grande are deep cut canyons--Santa Elena, Mariscal, and Boquillas--alternating with narrow valleys walled by towering cliffs (US Dept. of Interior, 1983). It is a region of large biological diversity containing more than 1,000 species of plants, including 65 cacti, 434 birds, 78 mammals, 71 reptiles and amphibians, and 35 fish (Big Bend Natural History Assoc., 1990). Endangered species include the peregrine falcon, black-capped vireo, Mexican long-nose bat, Big Bend gambusia (a fish), and three threatened cacti (Big Bend Natural History Assoc., 1990). Because of its contrasting landscapes, however, Big Bend is also known and appreciated for the beauty of its scenic vistas located in both countries.

Although early travelers called the land "*el despoblado*", the unpopulated land, there is a rich history associated with the land extending back in time to ca. 8500-6500