# Air Dispersion Modeling for the National Forest Service Oil & Gas Leasing Evaluation

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## ABSTRACT

Three of the western National Forests (Forest) underwent the NEPA process for assessing future oil and gas (O&G) exploration and production impacts. The standard arrays of environmental concerns were evaluated and cumulative impacts assessed in the Environmental Impact Statement (EIS) process, including air resources. Air resources impacts were especially challenging because the Proposed Action and Alternatives (PA&As) were based on potential but undefined leasing scenarios. Any PA&A would have to be evaluated anywhere within the Forest boundary and with emissions ranging from a dry exploratory well to a full production oil or gas well or combination of O&G wells. In addition, supporting equipment, length of access roads, fuel type, topography, and climatic conditions could all vary greatly depending on how, where and how many wells were drilled.

Our task was to effectively provide an assessment of the potential impact of both exploratory and production oil & gas wells on the air resources of the Forests. Determining worst-case and typical plant-based emissions and how they were emitted was challenging. Fulfilling the concerns of numerous non-governmental organizations, regulatory agencies, parties of interest, as well as the Forest Service proved its own divided challenge.

Our analytical dispersion modeling approach was multifaceted using ISCST3 for short term impacts while employing CALPUFF-lite for long range assessments. Maximum and minimum elevation changes were determined and proportioned for each modeling evaluation; radii of impacts were segmented; and generic emissions were calculated for regional expectations. (1)(8)(14) The results of our efforts were tabulated in a normalized 'look-up' table. This look-up or "screening table" allowed the Forest Service to determine if a particular parcel should be considered, be evaluated, or be excluded entirely from O&G exploration and/or development. In addition, performing this evaluation for all three Forest Service's Districts allowed for assessment consistency in the region.

## INTRODUCTION

A unique methodology using air quality modeling was employed to evaluate leasing options for various sites with three western National Forest Service (FS) lands to support their respective Environmental Impact Study (EIS). The potential for O&G exploration and future development had to be evaluated based on future, but nebulous, impacts. A screening approach and analysis of potential impacts of O&G emissions for exploration and production stage was presented to the FS and parties of interest (POI). As with typical modeling efforts, a modeling protocol was produced and distributed amongst land managers, U.S. Environmental Protection Agency (EPA) Region 8 and Utah air quality regulators. Comments were received, discussed, and incorporated into the modeling protocol. The overall FS goal was to evaluate all possible sites for air quality impacts by using the same approach, standards, and methodology.

The resulting analyses supported all three EIS evaluation processes by preparing a straightforward screening tool for land managers to estimate potential impact of criteria pollutant emissions on air quality and air quality related values (AQRVs). These analyses did not represent regulatory-based air quality impact analyses or secondary pollutants formation. Unless an oil field is classified as a new development, the permitting process is not required. If reserves are discovered in these Forests, development could have the potential to impact both the Forest and Class I areas. (12)(13) Development of potential resources identified during the leasing stage supported by the EIS process requires refined air quality analyses that would include project and site-specific information in order to further identify potential impacts.

## BACKGROUND

The objective of the Dixie, Fishlake, and Uinta National Forests PA&As was to determine the impact of limited O&G exploration leasing across their domains. The PA&A would have to be justified for significant development of oil or gas resources or any project-specific development. With these Forests located in central Utah, several Class I areas are located bordering these Forests.(11)(13) Any subsequent action would require further NEPA analyses, including refined air quality modeling analysis. The refined modeling would have the opulence of site-specific information such as location parameters, equipment specifications, and utility access. Note subsequent actions such as exploratory well drilling or production wells do not necessarily require regulatory source permitting (12)(4). These analyses considered the impacts of O&G leasing/exploration stage activities, but probably limited O&G field development scenarios.

The primary emphasis of the initial modeling analyses was to provide a quantified air dispersion analysis of potential impacts at the leasing stage exploration of O&G resources. The result of those analyses was normalized, and a set of conversion factors provided for various source types. Receptor elevation varied based on predetermined elevation changes within each Forest, as did the interval of the radii of impacts. These conversion factors can then be ramped up to most development scenarios and associated emission rates for various activity levels yielding a site-specific concentration value. These concentration values can then be used to derive conservative (worst-case actual) estimates of potential impacts to air quality and AQRVs. That information will allow land managers to estimate the potential for air quality impacts for subsequent O&G development projects.

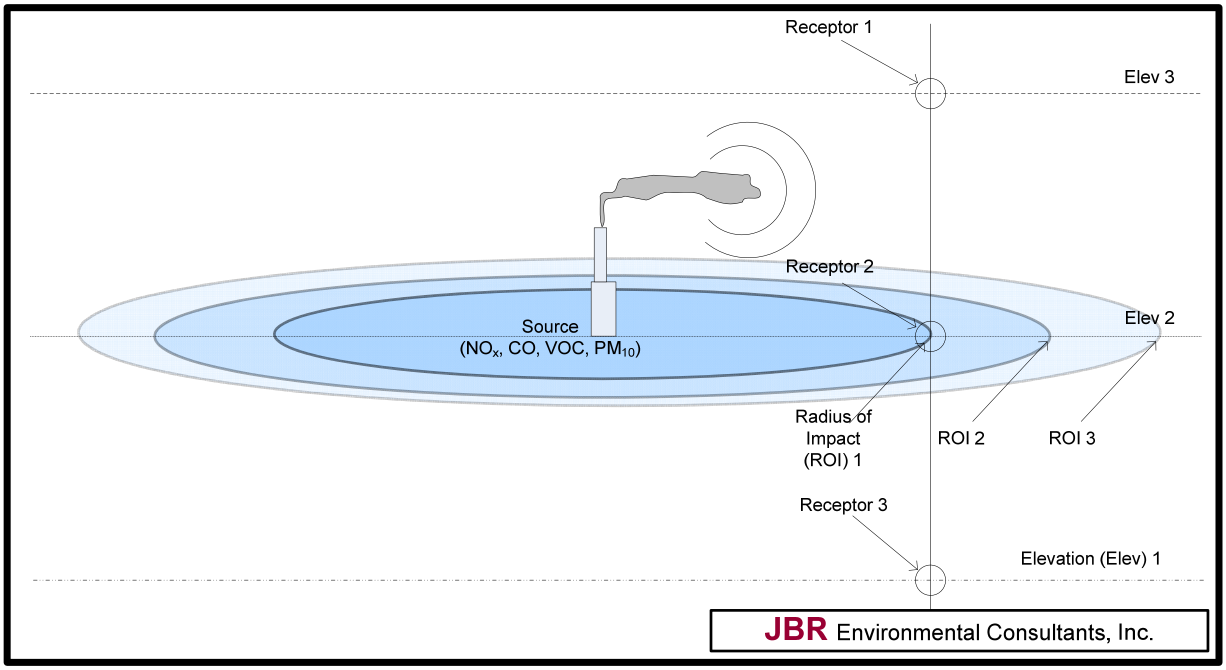
## MODELING METHODOLOGY

The EPA-approved model CALPUFF was used in the screening mode for the long-range transport analyses. The ISCST3 model utilized by Utah Division of Air Quality (UDAQ) to assess impacts for minor sources was used to conservatively estimate impacts in the near field.

The EPA screening model VISCREEN was used to assess visibility impacts in the near field. CALPUFF modeling results were post-processed to assess long-range transport pollutant concentrations and impacts on air quality and AQRVs.

Figure 1 shows our modeling approach for this evaluation visually. This depiction is accurate for the ISCST3 and VISCREEN runs. The CALPUFF dispersion model is more refined in that it tracks emissions as a continuous series of puffs, which can expand or change transport direction as meteorological conditions change. Each pollutant and air quality related value was evaluated at a predetermined elevation in relation to the source and radius of impact (ROI). Five elevation scenarios were considered. The ROI used are documented in the receptor network section below. Maximum values on each radius from the source were reported and included in the screening tables. Those results can be compared against applicable Class 1 or Class 2 impact limits or any other applicable impact limits for planning purposes.

**Figure 1. Modeling Methodology.**



## Model Source Data

Quantification of the equipment needed to support oil field development with some possibility of gas resources was prepared generally and specifically for the three development scenarios. To be conservative, worst-case assumptions were made of the type, size, and number of pieces for each equipment type. For example, a heated oil/gas/water separator and a gas flare were assumed at most well pads despite the potential for mechanical separating and/or one or a limited number of each type of equipment to service fields anticipated to be more likely to contain recoverable amounts of oil than natural gas. Also, emission estimates assume that all vehicular travel is on unpaved service, and that there is no electrical power service onsite, so all major equipment onsite is fossil fuel fired. (4) The three development scenarios considered were:

1. Individual exploratory wells between 45 and 60 are estimated on the Forest lands over the next 15 years, each with a period of approximately three weeks for construction, three months of exploration activity, and two weeks of reclamation,

2. A 10- to 15-well directional drilling development which features 2-3 well pads, and

3. A conventional 20-well oil field development featuring 20-well pads and associated oil extraction and processing operations over an area estimated at 3.5 square miles. (1)(6)(8)

Air quality modeling for each of these three development scenarios was performed to assess potential criteria air quality and AQRV impacts from conservative estimates of likely activity levels.

Estimates of volatile organic compound (VOC) emissions and offsite particulate emissions from each development scenario was prepared, but no modeling was performed for this stage, so no quantitative assessment was made of ambient air quality impacts associated with those emissions. References used to help quantify the numerous parameters for these development scenarios included Utah State Government's Analysis of Emissions from Oil and Gas Wells in Utah, UDAQ's Annual Reports, the Oil and Gas EI Workbook for the Uinta Basin Study, information from existing oil field development on the Dixie, Fishlake, and Uinta National Forest (i.e. Reasonable Foreseeable Development Scenarios) and regional and national O&G field emission analyses and emission factors.

Table 1 below documents the types of equipment with air emissions under each scenario. Emission rates in the screening modeling were normalized to one pound per hour (lb/hr). For the three verification scenarios, emission rates were representative of activity associated with each scenario. (4)(7) To be conservative, the emissions profile shown here assumes moderate to heavy oil extraction efforts for each scenario, with at least some gas to be flared or processed. As such, these estimates likely overestimate emissions of the non-reactive pollutants to be modeled. (17) Stack parameters representative of actual regional O&G extraction operations will be used. Model sources included the stack parameters listed in the table below. The first few columns show how these source types were distributed for each of the three verification scenarios. The model runs for the screening tables included source data representative of development possibilities, including each of the development scenarios used for model verification. Bolding indicates equipment that would be needed primarily or exclusively for gas development. Current indications are that only oil development is considered likely, so inclusion of these sources in the modeling analysis would represent a degree of conservatism.

**Table 1. Model Sources and Source Parameters.**

| **Scenario Site Layout** | | | **Model Stack Source Data (for each unit)** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Exploration site | 10 well directional production | 20 well production | Source ID | Source Description | Stack Height | Temperature | Exit Velocity | Stack Diameter |
| | | | | | (ft) | (°F) | (fps) | (ft) |
| 1 | 1 | 1 | DRE | Drill Rig Engine | 15.0 | 950.0 | 75.0 | 1 |
| 1 | | | EFLR | Exploration Flare | 75.0 | 1000.0 | 47.0 | 1.5 |
| | 1 per pad | 1 per every 4 wells | PFLR1 | Production Flare | 100.0 | 1000.0 | 55.0 | 1.5 |
| | **1** | **2** | **CM2** | **Compressor Engine** | **25.0** | **760.0** | **95.0** | **1** |
| | 1 per pad | 1 per well | HT1 | Heater Treater (Separator) | 20.0 | 180.0 | 15.0 | 0.67 |
| | **1 per pad** | **4 per field** | **DHY1** | **Dehydrator** | **30.0** | **200.0** | **8.0** | **1** |
| | 1 per pad | 1 per well | WP1 | Well Pump | 10.0 | 775.0 | 45.0 | 0.667 |

Actual development scenarios would include fugitive sources of VOCs and particulates. The verification model runs also included area and/or volume sources to assess the impacts of particulate emissions from ground disturbance and criteria pollutant emissions from vehicular traffic. Emission calculations were based upon studies performed by the State of Utah and the Highway Freight Traffic Associated with the Development of Oil and Gas Wells document prepared by Daniel Kuhn of the Utah Department of Transportation (UDOT) in October 2006 (15). The onsite emissions were evenly distributed around the facility in the model, with at least as strong a concentration near the activity area boundaries in the model as is likely during actual operations. This is considered conservative in this analysis, where the nearest receptors are one-half mile away. The percentage of overall traffic emissions associated with the project that occur within the project area boundary will be estimated conservatively high. Road and disturbed area emissions occurring outside the identified project area were addressed qualitatively, but were not modeled quantitatively.

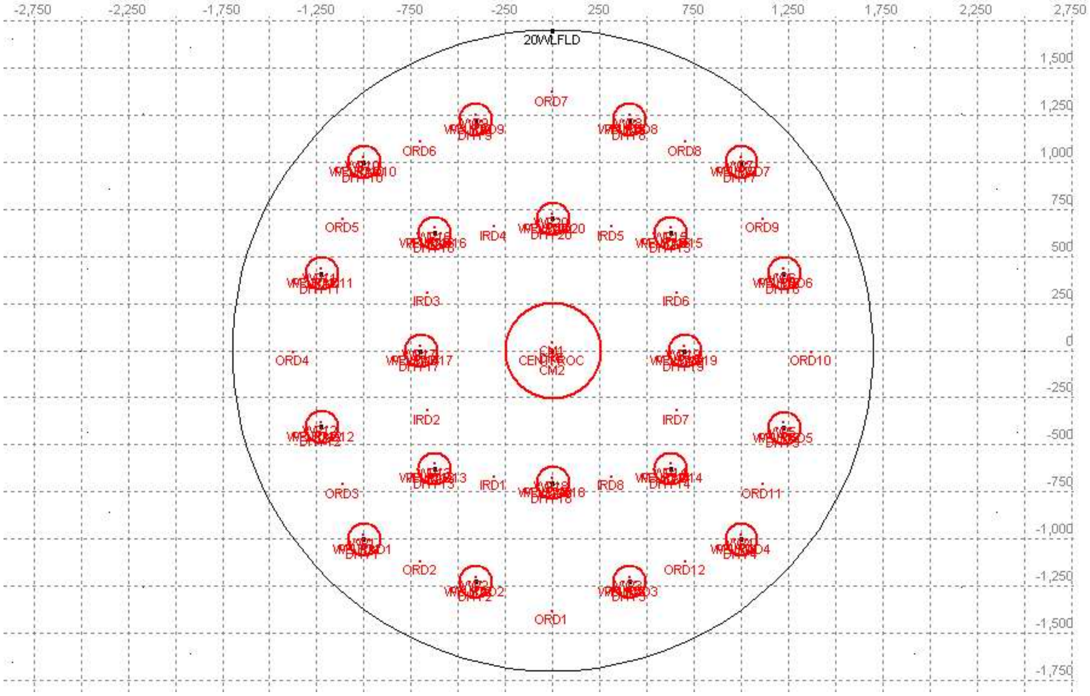
VISCREEN and CALPUFF analyses, and the model runs used to prepare the screening tables, were based upon the same emissions source data, though the emissions were combined into a smaller subset for computational simplicity. (3) That process follows VISCREEN guidance and requirements for the near-field analysis. For all but the nearest receptors, the differences in emission locations within the facility were insignificant in relation to the distance to receptors. Assuming all emissions are concentrated in the center of the development field will slightly increase the conservatism in the CALPUFF-based long range transport modeling results.

## Model Facility and Source Layout

The emissions scenarios for the screening table runs included a minimum number of emission points or area sources scaled to be representative of actual emissions from anticipated oil and/or O&G development. Visibility runs were based upon combined NOx and $SO_2$ emissions, based upon the conservative assumption that secondary particulate formation would not be limited by a lack of ammonia.

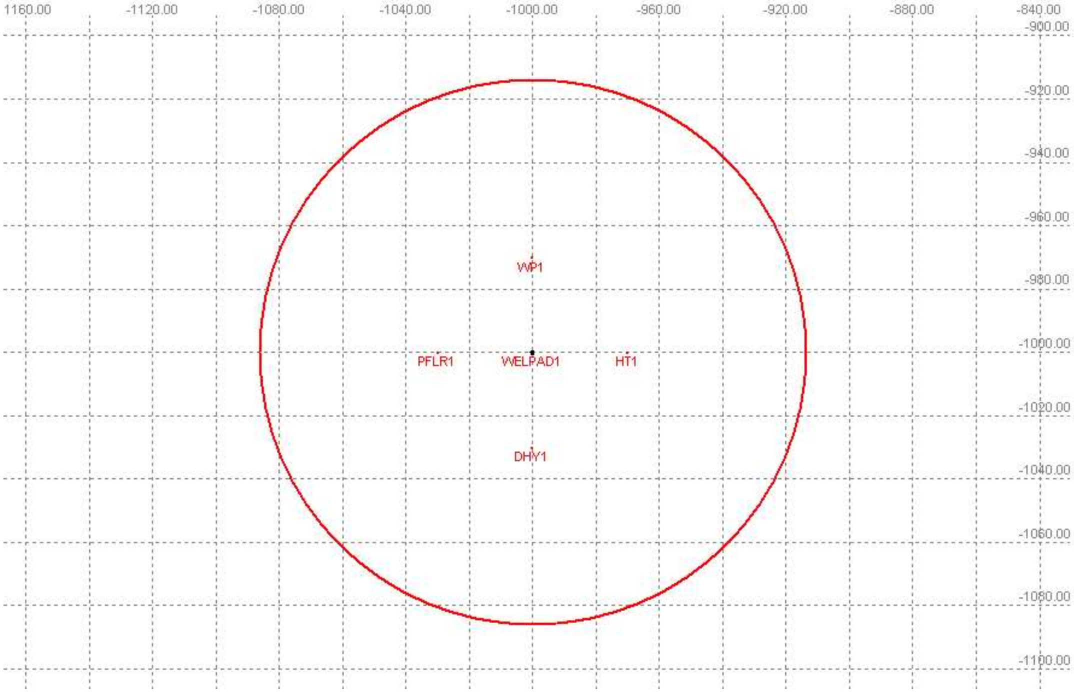
The screening tables were verified by modeling the three development scenarios determined likely by the FS as a result of this EIS action (exploratory drilling), or subsequent NEPA and permitting actions facilitated by the exploration proposed in the current EIS (10-15 well directional drilling, and 20-well conventional drilling). (5)(6) Figure 2 below shows the draft representative ISCST3 model layout for the hypothetical 20-well field used as one of the three verification scenarios. The black circle represents a 3.5 square mile area boundary anticipated by the FS. Model sources are shown and labeled in red. The layout figure shows 20-well pads around a central processing area. The central processing area includes two compressor engines. The fugitive emissions from roads and disturbed areas, other than well pads and the central processing area, were included in the model by a series of area or volume sources between the well pads. They are shown here as red dots labeled ORDx or IRDx (for inner or outer roads).

**Figure 2. ISCST3 Model 20 Well Oil Field Scenario Facility Layout.**



The details of what is at and around each well pad are shown in Figure 3.

**Figure 3. ISCST3 Model Source Layout for Each Well Field in the 20 Well Oil Field Scenario.**



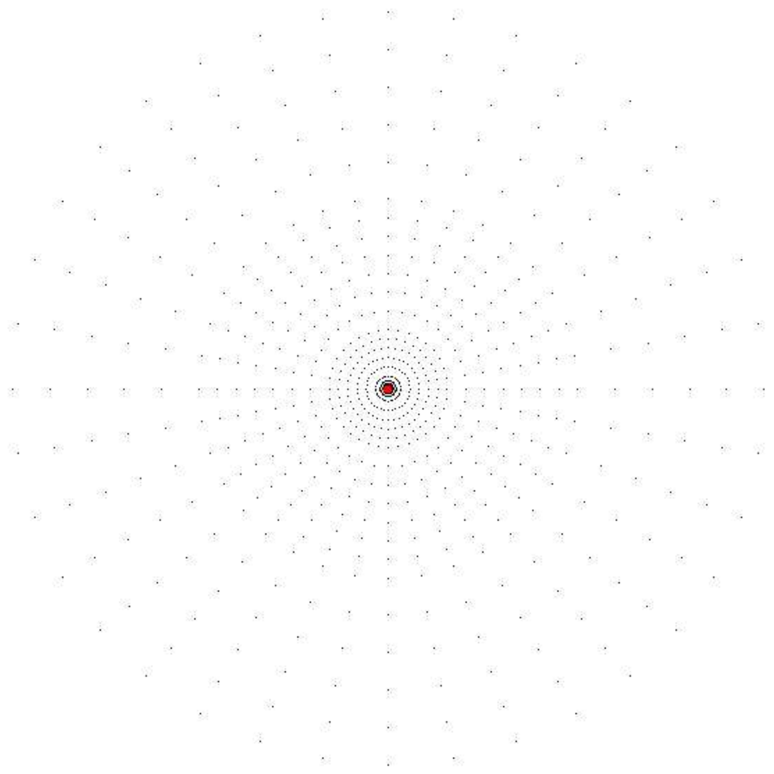
The 10- to 15-well directional drilling oil field development verification scenario featured fewer well pads over a smaller area, with potentially more concentrated activity in the vicinity of each well, based upon the FS development expectations. (5)(6) The exploration verification scenario conservatively assumed a 5.9 acre pad with 9 to 10.7 acres of road and other surface disturbances around or atop the pad, and all emissions within that small area.

Building downwash was not considered because the nearest receptors were well beyond all building or structure cavities.

## Model Domain, Mapping, and Receptor Network

The domain of the modeling analysis extended to 200 kilometers from the area of activity, or 322 to 323 kilometers from the center of each development scenario's activity. The receptor network for the analyses included rings of receptors around the activity area at distances of 0.5, 1, 2.5, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, and 200 kilometers. The figure below shows the model receptor network.

**Figure 4. Model Receptor Network.**



The ISCST3 model was used for pollutant concentrations within 50 kilometers (approximately 31 miles) of the activity area and the CALPUFF model was used beyond that distance. Visibility impacts were estimated with the model VISCREEN within 50 km, and by CALPUFF post-processing beyond, consistent with EPA and UDAQ guidance and discussions with UDAQ during project initiations.

Model receptors were placed at 2500 and 1000 feet above the source elevation, at the same elevation as the source, and at 1000 and 2500 feet below the source, in separate model runs for each elevation difference scenario. Those source / receptor elevation difference scenarios could be reconsidered to be consistent with elevation differences between likely development sites and nearby or regional Class 1 areas.

The CALPUFF visibility and wet deposition analyses require extended hourly meteorological data sets including relative humidity. Screening meteorological data were used consistent with Federal Land Managers Air Group (FLAG) guidance for worst-case whenever possible. Where necessary, meteorological data prepared from SAMSON data sets with extended ISC parameters were used. Verification model runs for potential development scenarios anticipated at the sites considered base elevations consistent with likely areas of development. Those analyses were used to verify that the screening table results will be representative of potential development scenarios on the Dixie, Fishlake, and Uinta National Forests.

## Meteorological Data

The normalized model analyses used to prepare the screening tables utilized an ISCST3-based screening meteorological data file and/or regional ISCST3 meteorological data files provided by UDAQ for the near-field impact analyses, with extended meteorological data where needed consistent with FLAG guidance. (2) Up to five years of meteorological data were used for the long-range transport analyses where necessary and/or for verification runs.

For the specific development scenario analyses planned to verify the screening tables, UDAQ recommended and provided ISCST3 meteorological data sets from four Met-data stations in the vicinity of the Dixie, Fishlake, and Uinta National Forests.

Rural dispersion coefficients are assumed to be appropriate for all locations where project development is anticipated. Land use in CALPUFF was considered forested or barren land as appropriate. CALPUFF plume elements were modeled as puffs. No boundary influx was included in the CALPUFF analysis.

## Discussion

The results of the screening modeling analyses were translated into a set of screening tables as described in the modeling protocol. The pollutant concentration screening runs were prepared using a screening meteorological data file. One-hour average maximum model predicted impacts were reported because the hourly data in those meteorological files was hypothetical; consecutive hours did not represent an actual time series. Therefore, the post-processing of the screening air concentration modeling runs consisted of taking model predicted maximum one-hour average impacts and applying persistence factors consistent with UDAQ modeling guidance to estimate model predicted impacts at averaging periods consistent with ambient air quality standards, increments and thresholds. (13) AQRV analyses were performed with three years of measured meteorological data. Model output values from the CALPOST post-processing program associated with CALPUFF in that modeling system were copied directly into the screening tables.

Model results from the verification runs were used to perform quality assurance checks on the screening table initially prepared from screening modeling results. As a result of those quality assurance checks, limited refinements were made in the screening table entries for near field $SO_2$ concentrations.

Each screening table developed shows maximum predicted impacts at each receptor ring distance for each source / receptor elevation difference scenario. The impacts included in these tables are normalized, based upon 1 lb/hr emissions. The normalized impacts can be used to estimate the potential impact of various O&G development scenarios considered in all the Forests. Using the 1 lb/hr emissions rate from a proposed project, one can estimate the screening impact by multiplying the screening table impact by the actual emissions for the project under consideration.

After the successful screening model runs, potential development scenarios described by the Dixie, Fishlake, and Uinta NFs were then modeled to assess concentrations of the air pollutants NOx, $SO_2$, and PM-10, with the activity set in arbitrarily chosen, conceivably developable locations on each NF. (1)(13)(8) The locations were chosen with some consideration of their O&G production potential, but also were selected by air quality scientists as topographically representative sites where development could occur. Receptors were placed in 21 rings around each of these development scenarios, at intervals consistent with the screening modeling receptors. Receptor elevations in the verification modeling used actual elevations from USGS digital elevation models. The primary goal was to estimate modeled impacts from the identified potential development scenario laid out in an area where it could conceivably occur. Another goal was to check how consistent modeled impacts, at receptors set at actual locations in rings surrounding that development, were with those predicted at those locations by the screening tables developed.

The verification model run comparison results for more distant receptors, and for the PM-10 short term 24-hour averaging period were shown to be reasonable, but conservative (not over predicting). For $SO_2$ short-term averaging impacts for receptors below or significantly above the model source, and to a lesser extent $NO_2$ impact projections for those areas, verification efforts identified a concern related to the predicted concentrations from a few sets of stack parameters in model runs used to prepare the screening tables. Diesel emissions, primarily from well pumps or drilling rigs, represented the vast majority of $SO_2$ and $NO_2$ emissions. Unlike PM-10, other emission categories like fugitive dust or gasoline vehicle engines did not contribute much to the $SO_2$ emission rate. (15) Screening model runs assume that all emissions occur at the same elevation, which is rarely the case in actual field locations in areas like the NFs studied. As a result, the screening runs' conservative impact projections showed a plume narrowly concentrated with significant concentration at nearby elevations but limited impacts at other elevations. Initial screening model runs tended to show impacts an order of magnitude higher for ISCST3 near-field receptors than those at the verification run source / receptor elevation differences. A closer look showed that this was caused by a plume very concentrated in the vertical in the screening runs which was not duplicated in the verification runs because the model sources in the verification runs varied in elevation by a few hundred feet. Therefore, this was determined to be a result of unrealistic plume concentration in the screening model runs. This model plume concentration effect occurred in the near-field ISCST3 model runs, most significantly for receptors below the emission source because the plume tended to be elevated slightly above ground level. More sophisticated atmospheric mixing algorithms, chemical interactions, and the longer transport distance and time in the CALPUFF model resulted in more homogenously mixed plumes for long-range transport.

Calculated statistics indicated that verification model $SO_2$ short-term (3-hour and 24-hour average) predictions for receptors at elevations higher or lower than the mean source elevation were often higher than maximum impacts calculated from the screening tables. Therefore, the screening tables were not initially conservative for short term $SO_2$ impact analyses. Those same calculations showed that the screening table values for receptors at the same elevation were always quite conservative when compared to verification model predicted maximum impacts for any source / receptor elevation difference.

For further quality assurance, the screening tables were scrutinized for reasonableness and internal consistency. Those checks identified inconsistencies in some variables across the transition from the near-field analyses prepared primarily using ISCST3 and the long-range transport analyses prepared using the CALPUFF model. Reviewers verified that there were inconsistencies across that transition line that are more likely an indication of differences of model internal calculation methodology than anything likely to be experienced in actual operations. However, no adjustments were made to the initial screening results for this condition. While the inconsistencies in model predicted concentration trends noted are not likely to be observed in the field, (3)(4)(13) the inconsistencies could occur when performing regulatory modeling, since they are a function of internal methodologies in the models that a permit applicant would be required to use during the regulatory process.

## RESULTS

For each of the three potential development scenarios identified by the USFS as representative of potential development, the equipment assumed to be operating to support the scenario development is described, and the screening table data are interpreted consistent with emissions from that equipment at anticipated operational levels to estimate maximum potential impacts. Those impact projections are conservative because they are based upon worst-case emission source layout and dispersion conditions. The long term average impact projections are conservative because they are based upon short term emission rates that would likely be higher than those anticipated on an annual basis.

The visibility impact projects are especially conservative because the normalized runs featured low emission rates. Low rate normalized runs account for the depletion of ammonia or competition between nitrates and sulfates for ammonia that occur with higher emission rates. These impact projections should be interpreted as worst-case scenarios. These scenarios represent the high end of potential impacts found in a refined air quality impact analysis, which is required for most development actions beyond initial exploration.

## Exploratory Drilling

This scenario is assumed to include the following activities that affect air quality:

- Construction of 5.5-acre drilling location – one exploratory well.
  - A diesel fuel fired drill rig engine with emissions consistent with the 13.5 tons NOx and 3.5 tons $SO_2$ per well.
  - The WRAP study indicated the mean drilling time is approximately 90 days per well, around the clock. Therefore, the longer term average impact predictions effectively assume four wells drilled back to back in relatively close proximity. (17)(9)
- Construction of 1.1 miles of new access roads.
- Support traffic to supply, maintain, and staff the drilling effort.
- A low volume of flaring of natural gas during exploration, equal to 100 Mscf per year. (1)

Table 2 below documents the predicted criteria pollutant $NO_2$, $SO_2$, and PM-10 concentrations, nitrate and sulfate deposition, and visibility impairment impacts at a variety of distances for three elevation difference scenarios.

## Table 2. Screening Impacts Predicted with the Exploratory Drilling Scenario.

| **Distance From Operating Area to Receptor (km)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 (km) | 2.5 km) | 5 (km) | 10 (km) | 15 (km) | 20 (km) | 30 (km) | 40 (km) | 50 (km) | 70 (km) | 100 (km) | 140 (km) | 200 (km) |
| **Receptors 2500 feet above Source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 19.03 | 6.28 | 1.49 | 0.50 | 0.16 | 0.09 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 |
| $SO_2$ | 3 hour | 44.54 | 14.41 | 12.19 | 6.35 | 2.82 | 1.73 | 0.78 | 0.62 | 0.06 | 0.03 | 0.02 | 0.01 | 0.00 |
| | 24 hour | 25.45 | 8.23 | 6.97 | 3.63 | 1.61 | 0.99 | 0.44 | 0.36 | 0.04 | 0.02 | 0.01 | 0.00 | 0.00 |
| | annual | 5.09 | 1.65 | 0.38 | 0.13 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 7.66 | 5.01 | 2.09 | 0.91 | 0.37 | 0.22 | 0.10 | 0.07 | 0.07 | 0.02 | 0.01 | 0.03 | 0.00 |
| | annual | 1.53 | 1.00 | 0.42 | 0.18 | 0.07 | 0.04 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| N Dep | kg/hect/yr | 0.0012 | 0.0006 | 0.0002 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| S Dep | kg/hect/yr | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Visibility | Days Δdv >0.5 | 1 | 1 | 1 | 2 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Days Δdv >1.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Receptors at same elevation as source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 19.74 | 12.49 | 6.27 | 2.88 | 1.81 | 1.31 | 0.84 | 0.61 | 0.07 | 0.02 | 0.01 | 0.00 | 0.00 |
| $SO_2$ | 3 hour | 35.77 | 23.26 | 11.60 | 5.27 | 3.26 | 2.36 | 1.49 | 1.20 | 0.13 | 0.03 | 0.01 | 0.01 | 0.00 |
| | 24 hour | 20.44 | 13.29 | 6.63 | 3.01 | 1.87 | 1.35 | 0.85 | 0.69 | 0.08 | 0.02 | 0.01 | 0.00 | 0.00 |
| | annual | 5.11 | 3.32 | 1.66 | 0.75 | 0.47 | 0.34 | 0.21 | 0.17 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 5.10 | 2.12 | 0.92 | 0.38 | 0.23 | 0.16 | 0.10 | 0.07 | 0.06 | 0.01 | 0.01 | 0.03 | 0.00 |
| | annual | 1.28 | 0.53 | 0.23 | 0.09 | 0.06 | 0.04 | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 |
| N Dep | kg/hect/yr | 0.0005 | 0.0002 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| S Dep | kg/hect/yr | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Visibility | Days Δdv >0.5 | **1.844** | **1.797** | **1.824** | **1.954** | **1.950** | **1.133** | **0.650** | **0.512** | **0.503** | **0.403** | **0.302** | **0.216** | **0.169** |
| | Days Δdv >1.0 | **20.3%** | **19.7%** | **20.0%** | **21.6%** | **21.5%** | **12.0%** | **6.7%** | **5.3%** | **5.2%** | **4.1%** | **3.1%** | **2.2%** | **1.7%** |
| **Receptors 1000 feet below source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 0.83 | 0.48 | 0.36 | 0.21 | 0.15 | 0.12 | 0.11 | 0.09 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| $SO_2$ | 3 hour | 18.61 | 12.05 | 6.12 | 2.82 | 1.76 | 1.29 | 0.84 | 0.68 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 |
| | 24 hour | 10.64 | 6.89 | 3.50 | 1.61 | 1.01 | 0.73 | 0.48 | 0.39 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| | annual | 0.21 | 0.12 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 5.01 | 2.09 | 0.91 | 0.37 | 0.22 | 0.16 | 0.10 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | annual | 1.25 | 0.52 | 0.23 | 0.09 | 0.06 | 0.04 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N Dep | kg/hect/yr | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| S Dep | kg/hect/yr | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Visibility | Days Δdv >0.5 | **0.182** | **0.214** | **0.278** | **0.681** | **0.306** | **0.394** | **0.298** | **0.322** | **0.441** | **0.392** | **0.264** | **0.206** | **0.147** |
| | Days Δdv >1.0 | **1.8%** | **2.2%** | **2.8%** | **7.0%** | **3.1%** | **4.0%** | **3.0%** | **3.3%** | **4.5%** | **4.0%** | **2.7%** | **2.1%** | **1.5%** |

## 12-Well Directional Drilling Development

This scenario is assumed to include the following activities that affect air quality:

- Construction of three 5.5-acre drilling locations.
    - One diesel fuel fired drill rig engine with emissions consistent with the 13.5 tons NOx and 3.5 tons $SO_2$ per well
    - The WRAP study indicated the mean drilling time is approximately 90 days per well, around the clock. Therefore, the longer term average impact predictions effectively assume four wells drilled back to back in relatively close proximity(17)
- Construction of 5 miles of new access roads.
- Support traffic to supply, maintain, and staff the drilling and pumping effort.
- Six 1.0 MMBtu/hr heater / treater separators, two at each well pad.
- Twelve diesel powered 100 hp well pumps to extract oil, one for each well.
- One 0.5 MMBtu/hr dehydrator and one 500 hp compressor processing a low volume of natural gas at partial capacity.(7)

Diesel well pumps are assumed because the development sites are expected to be remote from the electric power grid. Though a slight amount of natural gas production is included for conservatism, producible natural gas is not routinely expected, and is not anticipated in sufficient quantity to power the well pumps.

Table 3 below documents the predicted criteria pollutant $NO_2$, $SO_2$, and PM-10 concentrations, nitrate and sulfate deposition, and visibility impairment impacts at a variety of distances for three elevation difference scenarios.

## Table 3. Screening Impacts Predicted with the 12-Well Directional Drilling Scenario.

| **Distance From Operating Area to Receptor (km)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 (km) | 2.5 km) | 5 (km) | 10 (km) | 15 (km) | 20 (km) | 30 (km) | 40 (km) | 50 (km) | 70 (km) | 100 (km) | 140( km) | 200 (km) |
| **Receptors 2500 feet above Source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 31.30 | 7.42 | 2.47 | 0.82 | 0.44 | 0.28 | 0.16 | 0.11 | 0.10 | 0.07 | 0.03 | 0.02 | 0.01 |
| $SO_2$ | 3 hour | 26.02 | 22.01 | 11.47 | 5.08 | 3.12 | 2.24 | 1.41 | 1.13 | 0.11 | 0.05 | 0.03 | 0.01 | 0.01 |
| | 24 hour | 14.87 | 12.58 | 6.55 | 2.91 | 1.78 | 1.28 | 0.80 | 0.64 | 0.07 | 0.03 | 0.02 | 0.01 | 0.00 |
| | annual | 3.72 | 0.86 | 0.28 | 0.09 | 0.05 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 54.80 | 22.82 | 9.91 | 4.10 | 2.44 | 1.73 | 1.06 | 0.77 | 0.76 | 0.18 | 0.16 | 0.33 | 0.00 |
| | annual | 13.70 | 5.71 | 2.48 | 1.02 | 0.61 | 0.43 | 0.27 | 0.19 | 0.19 | 0.04 | 0.04 | 0.08 | 0.00 |
| N Dep | kg/hect/yr | 2.3937 | 0.8389 | 0.3649 | 0.1288 | 0.0672 | 0.0424 | 0.0197 | 0.0112 | 0.0068 | 0.0028 | 0.0014 | 0.0009 | 0.0006 |
| S Dep | kg/hect/yr | 0.0559 | 0.0301 | 0.0170 | 0.0096 | 0.0071 | 0.0051 | 0.0031 | 0.0021 | 0.0013 | 0.0007 | 0.0003 | 0.0002 | 0.0001 |
| Visibility | Days Δdv >0.5 | **6.010** | **5.867** | **5.937** | **6.273** | **6.226** | **3.898** | **2.345** | **1.830** | **1.819** | **1.458** | **1.102** | **0.794** | **0.613** |
| | Days Δdv >1.0 | **82.4%** | **79.8%** | **81.1%** | **87.2%** | **86.4%** | **47.7%** | **26.4%** | **20.1%** | **19.9%** | **15.7%** | **11.6%** | **8.3%** | **6.3%** |
| **Receptors at same elevation as source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 78.73 | 49.83 | 25.00 | 11.51 | 7.20 | 5.24 | 3.33 | 2.45 | 0.30 | 0.07 | 0.03 | 0.02 | 0.01 |
| $SO_2$ | 3 hour | 64.60 | 42.01 | 20.94 | 9.51 | 5.89 | 4.26 | 2.68 | 2.17 | 0.24 | 0.05 | 0.03 | 0.01 | 0.01 |
| | 24 hour | 36.91 | 24.00 | 11.97 | 5.43 | 3.37 | 2.43 | 1.53 | 1.24 | 0.14 | 0.03 | 0.01 | 0.01 | 0.00 |
| | annual | 9.23 | 6.00 | 2.99 | 1.36 | 0.84 | 0.61 | 0.38 | 0.31 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 55.78 | 23.12 | 10.03 | 4.15 | 2.47 | 1.75 | 1.08 | 0.77 | 0.67 | 0.16 | 0.14 | 0.29 | 0.01 |
| | annual | 13.94 | 5.78 | 2.51 | 1.04 | 0.62 | 0.44 | 0.27 | 0.19 | 0.17 | 0.04 | 0.04 | 0.07 | 0.00 |
| N Dep | kg/hect/yr | 1.9144 | 0.7527 | 0.3398 | 0.1226 | 0.0644 | 0.0409 | 0.0191 | 0.0108 | 0.0066 | 0.0027 | 0.0014 | 0.0008 | 0.0005 |
| S Dep | kg/hect/yr | 0.0385 | 0.0231 | 0.0140 | 0.0075 | 0.0058 | 0.0043 | 0.0027 | 0.0019 | 0.0014 | 0.0007 | 0.0004 | 0.0002 | 0.0001 |
| Visibility | Days Δdv >0.5 | **5.845** | **5.727** | **5.770** | **6.106** | **6.111** | **3.807** | **2.267** | **1.802** | **1.788** | **1.458** | **1.102** | **0.794** | **0.613** |
| | Days Δdv >1.0 | **79.4%** | **77.3%** | **78.1%** | **84.1%** | **84.2%** | **46.3%** | **25.4%** | **19.7%** | **19.6%** | **15.7%** | **11.6%** | **8.3%** | **6.3%** |
| **Receptors 1000 feet below source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 3.29 | 1.92 | 1.45 | 0.84 | 0.58 | 0.49 | 0.43 | 0.36 | 0.08 | 0.03 | 0.01 | 0.01 | 0.01 |
| $SO_2$ | 3 hour | 33.61 | 21.77 | 11.05 | 5.09 | 3.18 | 2.32 | 1.51 | 1.23 | 0.07 | 0.02 | 0.01 | 0.01 | 0.01 |
| | 24 hour | 19.20 | 12.44 | 6.31 | 2.91 | 1.82 | 1.33 | 0.87 | 0.70 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 |
| | annual | 0.37 | 0.22 | 0.17 | 0.10 | 0.07 | 0.06 | 0.05 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 54.80 | 22.82 | 9.91 | 4.10 | 2.44 | 1.73 | 1.06 | 0.77 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| | annual | 13.70 | 5.71 | 2.48 | 1.02 | 0.61 | 0.43 | 0.27 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N Dep | kg/hect/yr | 0.0064 | 0.0119 | 0.0081 | 0.0046 | 0.0039 | 0.0036 | 0.0030 | 0.0024 | 0.0021 | 0.0015 | 0.0011 | 0.0007 | 0.0005 |
| S Dep | kg/hect/yr | 0.0008 | 0.0010 | 0.0012 | 0.0009 | 0.0007 | 0.0006 | 0.0005 | 0.0005 | 0.0004 | 0.0003 | 0.0003 | 0.0002 | 0.0001 |
| Visibility | Days Δdv >0.5 | **0.668** | **0.791** | **1.031** | **2.442** | **1.125** | **1.443** | **1.096** | **1.184** | **1.613** | **1.441** | **0.974** | **0.760** | **0.541** |
| | Days Δdv >1.0 | **6.9%** | **8.2%** | **10.9%** | **27.7%** | **11.9%** | **15.5%** | **11.6%** | **12.6%** | **17.5%** | **15.5%** | **10.2%** | **7.9%** | **5.6%** |

The conservatism in the modeling analyses is clearly visible in the visibility impact analysis results. The results show potential increases in $b_{ext}$ over the FLAG suggested screening threshold for Class I areas of 10 percent out to 115 kilometers (71.5 miles). Deposition rates drop below FLAG screening thresholds of 0.005 kg/hect/year within 60 km (37.3 miles). Criteria pollutant impacts are shown to potentially approach NAAQS concentration limits with background concentrations added, in the near vicinity of development activity, but to drop off to impacts considered insignificant in Class II areas within 40 km (24.5 miles) for NOx and in less than 10 km (6.2 miles) for all other pollutants. Compared against Class I area significant impact limits, criteria pollutant impacts are predicted to insignificant within 65 km (40.4 miles) for all pollutants. When predicted impacts are below Class I impact limits, cumulative incremental degradation impact analyses are not likely necessary. Therefore, this screening analysis cannot rule out the need to perform a cumulative impact analysis for criteria pollutants if Class I areas exist within 40.4 miles.

Verification modeling analyses with realistic layout of equipment in potentially sensible locations using regional meteorological data files indicate low probability of exceeding ambient air quality standards, increments and/or thresholds nearby (with reasonable dust control), and show distances to those impact thresholds two to three times lower than predicted by the screening modeling.

The emission inventory for this analysis was conservative in that it assumed one new well was being drilled while the full field is operating, and also assumed that diesel fired pumps would be used at each well head. NOx, $SO_2$, and visibility impacts would decrease by approximately 20 percent if either no well drilling occurred simultaneously with the operation of 12 wells, or if enough natural gas was recovered onsite to fuel the well pumps. NOx, $SO_2$, and visibility impacts would be approximately 90 percent lower if electric power lines are brought power onsite, and no fuel was needed to operate the well pumps.

## 20-Well Conventional Drilling Development

This scenario is assumed to include the following activities that affect air quality:

- Construction of twenty 5.5-acre drilling locations.
    - One diesel fuel fired drill rig engine with emissions consistent with the 13.5 tons NOx and 3.5 tons $SO_2$ per well (17)(10)
    - The WRAP study indicated the mean drilling time is approximately 90 days per well, around the clock. Therefore, the longer term average impact predictions effectively assume four wells drilled back to back in relatively close proximity.
- Construction of 8 miles of new access roads.
- Support traffic to supply, maintain, and staff the drilling and pumping effort.
- Twenty 0.5 MMBtu/hr heater / treater separators, two at each well pad.
- Twenty diesel powered 100 hp well pumps to extract oil, one for each well.
- One 1.0 MMBtu dehydrator and one 500 hp compressor processing a low volume of natural gas at partial capacity. (1)(9)

Diesel well pumps are assumed because the development sites are expected to be remote from the electric power grid. Though a slight amount of natural gas production is included for conservatism, producible natural gas is not assumed in the RFDS, and is not anticipated in sufficient quantity to power the well pumps.

Table 4 documents the predicted criteria pollutant $NO_2$, $SO_2$, and PM-10 concentrations, nitrate and sulfate deposition, and visibility impairment impacts at a variety of distances for three elevation difference scenarios.

**Table 4. Screening Impacts Predicted with the 20-Well Conventional Drilling Scenario.**

| **Distance From Operating Area to Receptor (km)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1(km) | 2.5 (km) | 5 (km) | 10 (km) | 15(km) | 20 (km) | 30 (km) | 40 (km) | 50 (km) | 70 (km) | 100 (km) | 140 (km) | 200 (km) |
| Receptors 2500 feet above Source | | | | | | | | | | | | | | |
| $NO_2$ | annual | 46.05 | 10.91 | 3.64 | 1.21 | 0.64 | 0.41 | 0.23 | 0.17 | 0.15 | 0.11 | 0.05 | 0.03 | 0.01 |
| $SO_2$ | 3 hour | 33.76 | 28.56 | 14.88 | 6.60 | 4.05 | 2.91 | 1.82 | 1.46 | 0.15 | 0.07 | 0.04 | 0.02 | 0.01 |
| | 24 hour | 19.29 | 16.32 | 8.50 | 3.77 | 2.31 | 1.66 | 1.04 | 0.84 | 0.08 | 0.04 | 0.02 | 0.01 | 0.01 |
| | annual | 4.82 | 1.12 | 0.37 | 0.12 | 0.06 | 0.04 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 |
| PM-10 | 24 hour | 81.13 | 33.79 | 14.67 | 6.07 | 3.61 | 2.56 | 1.57 | 1.13 | 1.12 | 0.26 | 0.24 | 0.49 | 0.00 |
| | annual | 20.28 | 8.45 | 3.67 | 1.52 | 0.90 | 0.64 | 0.39 | 0.28 | 0.28 | 0.06 | 0.06 | 0.12 | 0.00 |
| N Dep | kg/hect/yr | 3.5215 | 1.2342 | 0.5368 | 0.1894 | 0.0989 | 0.0624 | 0.0290 | 0.0164 | 0.0100 | 0.0042 | 0.0020 | 0.0013 | 0.0008 |
| S Dep | kg/hect/yr | 0.0726 | 0.0390 | 0.0221 | 0.0124 | 0.0092 | 0.0066 | 0.0040 | 0.0027 | 0.0017 | 0.0009 | 0.0005 | 0.0003 | 0.0002 |
| Visibility | Days Δdv >0.5 | **7.931** | **7.756** | **7.836** | **8.241** | **8.190** | **5.301** | **3.270** | **2.575** | **2.561** | **2.070** | **1.575** | **1.141** | **0.883** |
| | Days Δdv >1.0 | **121.0%** | **117.2%** | **118.9%** | **128.0%** | **126.8%** | **69.9%** | **38.7%** | **29.4%** | **29.2%** | **23.0%** | **17.1%** | **12.1%** | **9.2%** |
| **Receptors at same elevation as source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 115.83 | 73.31 | 36.78 | 16.93 | 10.60 | 7.70 | 4.90 | 3.60 | 0.44 | 0.10 | 0.05 | 0.03 | 0.01 |
| $SO_2$ | 3 hour | 83.82 | 54.51 | 27.18 | 12.34 | 7.65 | 5.52 | 3.48 | 2.81 | 0.31 | 0.07 | 0.03 | 0.02 | 0.01 |
| | 24 hour | 47.90 | 31.15 | 15.53 | 7.05 | 4.37 | 3.16 | 1.99 | 1.61 | 0.18 | 0.04 | 0.02 | 0.01 | 0.00 |
| | annual | 11.97 | 7.79 | 3.88 | 1.76 | 1.09 | 0.79 | 0.50 | 0.40 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 82.58 | 34.23 | 14.84 | 6.14 | 3.65 | 2.59 | 1.59 | 1.15 | 0.99 | 0.23 | 0.21 | 0.44 | 0.02 |
| | annual | 20.64 | 8.56 | 3.71 | 1.53 | 0.91 | 0.65 | 0.40 | 0.29 | 0.25 | 0.06 | 0.05 | 0.11 | 0.00 |
| N Dep | kg/hect/yr | 2.8163 | 1.1073 | 0.4999 | 0.1804 | 0.0948 | 0.0601 | 0.0281 | 0.0159 | 0.0097 | 0.0040 | 0.0020 | 0.0012 | 0.0007 |
| S Dep | kg/hect/yr | 0.0500 | 0.0300 | 0.0182 | 0.0097 | 0.0075 | 0.0056 | 0.0035 | 0.0024 | 0.0019 | 0.0010 | 0.0005 | 0.0003 | 0.0002 |
| Visibility | Days Δdv >0.5 | **7.730** | **7.587** | **7.636** | **8.043** | **8.051** | **5.184** | **3.165** | **2.537** | **2.520** | **2.070** | **1.575** | **1.141** | **0.883** |
| | Days Δdv >1.0 | **116.6%** | **113.5%** | **114.6%** | **123.5%** | **123.7%** | **67.9%** | **37.2%** | **28.9%** | **28.7%** | **23.0%** | **17.1%** | **12.1%** | **9.2%** |
| **Receptors 1000 feet below source** | | | | | | | | | | | | | | |
| $NO_2$ | annual | 4.84 | 2.83 | 2.14 | 1.23 | 0.86 | 0.72 | 0.64 | 0.53 | 0.11 | 0.04 | 0.02 | 0.01 | 0.01 |
| $SO_2$ | 3 hour | 43.61 | 28.24 | 14.34 | 6.60 | 4.13 | 3.01 | 1.97 | 1.59 | 0.09 | 0.02 | 0.01 | 0.01 | 0.01 |
| | 24 hour | 24.92 | 16.14 | 8.19 | 3.77 | 2.36 | 1.72 | 1.12 | 0.91 | 0.05 | 0.01 | 0.01 | 0.01 | 0.00 |
| | annual | 0.49 | 0.28 | 0.21 | 0.12 | 0.09 | 0.07 | 0.06 | 0.05 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM-10 | 24 hour | 81.13 | 33.79 | 14.67 | 6.07 | 3.61 | 2.56 | 1.57 | 1.13 | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 |
| | annual | 20.28 | 8.45 | 3.67 | 1.52 | 0.90 | 0.64 | 0.39 | 0.28 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| N Dep | kg/hect/yr | 0.0094 | 0.0175 | 0.0119 | 0.0068 | 0.0057 | 0.0053 | 0.0044 | 0.0036 | 0.0030 | 0.0023 | 0.0016 | 0.0011 | 0.0007 |
| S Dep | kg/hect/yr | 0.0010 | 0.0014 | 0.0016 | 0.0011 | 0.0009 | 0.0008 | 0.0007 | 0.0006 | 0.0006 | 0.0004 | 0.0003 | 0.0002 | 0.0002 |
| Visibility | Days Δdv >0.5 | **0.963** | **1.137** | **1.477** | **3.410** | **1.609** | **2.052** | **1.567** | **1.691** | **2.286** | **2.048** | **1.397** | **1.094** | **0.782** |
| | Days Δdv >1.0 | **10.1%** | **12.0%** | **15.9%** | **40.6%** | **17.5%** | **22.8%** | **17.0%** | **18.4%** | **25.7%** | **22.7%** | **15.0%** | **11.6%** | **8.1%** |

The conservatism in the modeling analyses is apparent in the visibility impact analysis results. The results show potential increases in $b_{ext}$ over the FLAG suggested screening threshold for Class I areas of 10 percent out to almost 170 kilometers (105.6 miles). Deposition rates drop below FLAG screening thresholds of 0.005 kg/hect/year within 67 km (41.6 miles). Criteria pollutant impacts are shown to potentially approach NAAQS limits with background concentrations added, in the near vicinity of the development activity, but to drop off to impacts considered insignificant in Class II areas within 50 km (31 miles) for NOx and in less than 13 km (8.1 miles) for all other pollutants. Compared against Class I area impact limits, criteria pollutant impacts are predicted to be insignificant within 70 km (43.5 miles) for all pollutants. When predicted impacts are below Class I impact limits, cumulative incremental degradation impact analyses are not likely necessary. Therefore, this screening analysis cannot rule out the need to perform a cumulative impact analysis for criteria pollutants if Class I areas exist within 43.5 miles.

Verification modeling analyses show basically the same modeling results. Using our assumed layout of equipment, locations and regional meteorological data the results indicate a low probability of exceeding ambient air quality standards, increments and/or thresholds.

The emission inventory for this analysis was conservative in that it assumed one new well was being drilled while the full field is operating, and also assumed that diesel fired pumps would be used at each well head. NOx, $SO_2$, and visibility impacts would decrease by approximately 20 percent if either no well drilling occurred simultaneously with the operation of 12 wells, or if enough natural gas was recovered onsite to fuel the well pumps. NOx, $SO_2$, and visibility impacts would be approximately 90 percent lower if electric power lines are brought power onsite, and no fuel was needed to operate the well pumps.

## SUMMARY

In summary, the verification process resulted in refinements to the initial near-field short-term average $SO_2$ screening table results reflected in the refined screening tables and resulted in some instructions to be included in the User's Guide (to be completed) when applying screening table results for large well field developments. Identified minor inconsistencies at the 50-km distance, where the model required for regulatory analyses changes, were left in place because they were a result of the regulatory model choices likely required in subsequent regulatory analyses.

This screening analysis for the NF "typical 20-well field" scenario, using a set of reasonable assumptions for lay-out, equipment, and associated emissions shows the need to perform a cumulative impact analysis for criteria pollutants if Class I areas exist within 43.5 miles.

The screening analysis for the NF "typical 12-well field", using a set of reasonable assumptions for field lay-out, equipment, activities and associated emissions shows the need to perform a cumulative impact analysis for criteria pollutants if Class I areas exist within 40.4 miles.

The visibility analyses for the development scenarios showed that isolated exploratory wells were not likely to have any significant impact, but that either of the development scenarios could have visibility impacts out to 50 to 100 kilometers or possibly beyond. Those estimates are driven by the assumption of diesel fueled well pumps. If natural gas could be recovered in sufficient quantity to power the well pumps, the extent of potential visibility impacts would drop by approximately one third. If electric power was available without onsite generators, which was indicated as unlikely until well into the life of a productive field, emissions of pollutants affecting visibility impacts would be three to five times lower than those used for the visibility impact analyses reported here. Much lower visibility impacts could be estimated using the screening tables.

Our reasonable assumptions are subject to change and refinement given further definition of wells, well fields and their characteristics that have the potential to be developed. Thus, these predicted distances are only for gauging if cumulative impact analysis should be considered. However, given the development scenarios, with no specific location, equipment, well characteristics and pollutant emitting support operations, this approach and resulting screening tables gives the FS a reasonable tool in evaluating O&G ventures in the future. Consistency amongst the three Forests will result in a common approach and evaluation process for these resources.

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## KEYWORDS

AWMA, environmental, air dispersion modeling, Oil & Gas, NEPA