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Technical Review of Visibility Modeling for the Second Round of Regional Haze State Implementation Plans: State of Louisiana

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Introduction and Background

This report provides a technical review of the visibility modeling effort that has been conducted by the State of Louisiana to aid in development of the second round of regional haze State Implementation Plans (SIPs).

Technical documents reviewed were those posted to the State of Louisiana Department of Environmental Quality (LDEQ) webpage[1,2] along with the Central States Air Resources Agencies (CENSARA) webpage[3]. The LDEQ visibility modeling effort has relied in part on technical studies completed by CENSARA.

General Comments

There are several overriding issues with the LDEQ visibility modeling effort conducted in support of the second-round Regional Haze SIP. These issues are discussed below.

A principal objective of the second-round Regional Haze SIP was to identify sources that are believed to contribute to visibility impairment after the imposition of Best Available Retrofit Technology (BART) emission controls, which occurred in the first round of the Regional Haze SIP planning. Emission sources that continue to contribute to visibility impairment would then be subject to a "four-factor" analysis to determine the suitability of additional controls to reduce visibility precursor emissions.

The technical evaluation by LDEQ to select emission sources subject to the "four-factor" analysis needed to be appropriately inclusive. Simply put, the LDEQ analysis needed to identify those existing emission sources that contributed to ongoing visibility impairment and such emission sources would then be subjected to the required "four-factor" analysis to decide if additional emission controls or reductions might be warranted. The LDEQ criteria for selecting contributing sources was overly restrictive and therefore excluded emission sources that continue to degrade Class I area visibility.

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[1] LDEQ Source Selection Summary for Regional Haze Planning Period II
[2] LDEQ Spreadsheet: RH_PP2_SourceSelection_Version_2-1.xlsx
[3] https://www.censara.org

In the case of the LDEQ visibility modeling, the analysis identified only those emission sources determined to exhibit the largest contributions to ongoing visibility impairment. While identification of the most significant contributors to visibility impairment might be useful information, it was improper to restrict the scope of the "four-factor" emissions control analysis by excluding other sources that also contribute to visibility impairment. For Louisiana to improve current visibility conditions and meet the national goal to eliminate all anthropogenic visibility impairment before 2064, the LDEQ SIP planning effort should have identified additional important contributing sources beyond just the top contributing sources. LDEQ would have accomplished this if it had established its contribution thresholds to capture a broader grouping of sources. The issue of the thresholds used by LDEQ to select the contributing sources is discussed later in these comments.

In addition, the LDEQ second-round visibility modeling addressed visibility impacts by only considering the cumulative effect of nitrogen oxide (NOx) and sulfur dioxide (SO_2) emissions. This approach was also improper. Any individual emissions source most likely contributes to visibility impairment through either NOx or SO_2 effects. In addition, the adverse visibility impairment on any particular day would be most likely due to either sulfate (SO_2 emissions) or nitrate (NOx emissions). The distribution of the most-impaired days also likely showed some seasonality, with the wintertime period being more influenced by NOx emissions; i.e., nitrate levels are temperature-dependent and tend to be higher during the colder winter months. For these reasons, visibility impairment days tend to be dominated by a single pollutant, i.e., either sulfate or nitrate.

The LDEQ thresholds for selecting contributing sources should have looked at NOx and SO_2 emissions individually in addition to the combined NOx and SO_2 effects. Sources that contributed to either NOx and/or SO_2 visibility effects individually should not have been allowed to escape the "four-factor" analysis. Nevertheless, the LDEQ approach for the identification of emission sources contributing to visibility impairment allowed for such a potential outcome.

Technical Discussion

Back-Trajectory Modeling Analysis

The Louisiana Regional Haze SIP visibility modeling analysis relied upon an "area of influence" analysis by computing back-trajectories using the Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model. The back-trajectories were created for the 20% most anthropogenically impaired days over the period 2012-16. The HYSPLIT modeling was completed by Ramboll under their contract agreement with CENSARA.

The HYSPLIT modeling itself should be improved. Based on the documentation provided by CENSARA and LDEQ, HYSPLIT was executed to compute back-trajectories only for the grid cells that contained Class I monitors from the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. A better approach commonly used by other researchers who apply HYSPLIT would have been to compute back-trajectories using the "ensemble mode", which calculates back-trajectories using a 3x3x3 array of grid cells surrounding the IMPROVE monitor location. Past experience with HYSPLIT indicates that back-trajectories are quite sensitive to the starting location of the individual back-trajectory, and especially the starting location in the vertical.[4] The HYSPLIT "ensemble mode" better accounts for potential errors in the calculated back-trajectory along with other uncertainties inherent to HYSPLIT. These errors also become more pronounced as the length of the trajectory increases. As such, the "ensemble mode" generally performs better when the emission source is located further from the Class I area. In the end, the HYSPLIT "ensemble mode" would have provided for more robust back-trajectory statistics, especially for more distant emission sources.[5,6]

Another factor weighing in favor of using HYSPLIT in the "ensemble mode" is that Class I areas of interest are oftentimes larger than the size of an individual grid cell. In the HYSPLIT modeling approach used by CENSARA/LDEQ, the model only identified cases of emissions transport to the IMPROVE monitoring location. However, adverse visibility impacts may extend to portions of the Class I area away from the IMPROVE monitor location. By computing back-trajectories only for the IMPROVE monitor location, the CENSARA/LDEQ HYSPLIT modeling missed potential conditions where a source may adversely impact visibility in Class I grid cells without an IMPROVE monitor.

The HYSPLIT errors described above can also be more pronounced in situations where the IMPROVE monitoring site is located near the edge of the grid cell and the initial meteorological conditions may actually be better described by the adjacent grid cell.

Emissions Inventory

The LDEQ second-round visibility modeling applied an emissions inventory created for 2017.

One issue with the 2017 inventory selected by LDEQ is that the HYSPLIT back-trajectories were computed for the 20% most impaired visibility days identified for 2012-16 using the IMPROVE monitoring data. This mismatch between the emissions inventory period and the IMPROVE monitoring period introduced an unknown error into the HYSPLIT analysis. The 2017 emissions inventory was likely significantly different when compared to the inventory for the 2012-16 monitoring period. Instead, the LDEQ emissions inventory should have been matched with the IMPROVE data, either by sliding the inventory year or the IMPROVE monitoring period to create the desired overlap. There is no confidence that emission sources contributing to the 20% most impaired days were properly identified by LDEQ given that a mismatch existed between the emissions data and the IMPROVE monitoring data.

In addition, LDEQ has not demonstrated that the 2017 emissions were appropriately representative of normal operating conditions for emission sources across the modeling domain. Many emission sources, and especially large electric generating units (EGUs) that produce large quantities of visibility precursor emissions, exhibit substantial year-to-year variability in emissions. For example, at the Brame Energy Center (Brame) near Alexandria, LA, the 2018 and 2019 emissions were higher compared to the 2017 inventory used by LDEQ. For NOx, the emissions were higher in both 2018 and 2019, with the peak year (2018) higher by almost 70% (over 1,700 tpy). For SO_2, the emissions were higher in 2018 by about 35% (more than 1,850 tpy). The Brame emissions inventory comparison is shown in the table below.

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[4] Gebhart, K.A., et al 2005.

[5] Gebhart, K.A., et al 2018

[6] Gebhart, K.A., et al 2014

Brame Energy Center Emissions

	NOx Emissions (tpy)	SO_2 Emissions (tpy)
2017	2585	5179
2018	4362	7042
2019	3736	4739

Based on the LDEQ modeling evaluation which used the 2017 emissions, the Brame Energy Center appears to have been excluded from the requirement to conduct a "four-factor" emissions control analysis.[7] However, if the higher emissions from 2018 and 2019 had been used instead, this outcome would likely have been different. LDEQ needed to better justify why 2017 emissions were used for the analysis of contributing emission sources. A better approach for larger emission sources like EGUs that show substantial annual emissions variability would have been to use maximum annual emissions over a representative multi-year time period.

The 2017 inventory was also faulty in that it used the annual emissions (e.g., tons per year) for the various computations. Under the Regional Haze Rule, the evaluation of the visibility impacts occurring on the most-impaired and least-impaired days in a Class I area requires consideration short-term emissions, e.g., daily emissions, and not annual emissions. For EGUs, which are known to be a major contributor to visibility precursor emissions, the emissions on a daily basis vary considerably. As such, actual emissions at an individual emission source such as an EGU could in fact have been significantly higher on the 20% most impaired days compared to the annual average emissions. In fact, it might be reasonably expected that actual emissions at EGUs and other contributing emission sources would be higher than average on the 20% most-impaired days, i.e., the higher emissions caused a particular day to fall in the 20% most-impaired category. This outcome was not captured using the LDEQ visibility modeling approach.

Nearly all large EGUs report short-term emissions via continuous emission monitoring systems (CEMS). As such, LDEQ could have tabulated historical CEMS emissions data and identified the average daily NOx and SO_2 emissions occurring on the same 20% most-impaired days modeled with HYSPLIT. This approach would have provided emissions data representative of the desired short-term emission values. Also, in the absence of other data on short-term emissions. the US Environmental Protection Agency (EPA) has recommended that the annual average emissions be increased by a factor of two in order to adjust the emissions inventory to the required short-term emissions values.[8]

The approach used by LDEQ to rely on 2017 annual emissions likely underestimated the actual visibility impairment from one or more emission sources on the 20% most-impaired days. One method of accounting for the known day-to-day emissions variability at EGUs and other large sources of visibility precursor emissions would have been to ensure that the selection criteria used to identify contributing emission sources was appropriately inclusive and not overly restrictive.

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[7] LDEQ Spreadsheet: RH_PP2_SourceSelection_Version_2-1.xlsx

[8] USEPA 2014.

Extinction-Weighted Residence Time

The primary output of HYSPLIT was the calculation of "residence time", or the time that a particular back-trajectory from a Class I area spent in the grid square containing the individual emission source of interest. For the LDEQ area of influence analysis, the residence time was weighted by the extinction coefficient for the visibility precursors, namely sulfate (SO_4) and nitrate (NO_3). This value was denoted as the "extinction-weighted residence time" (EWRT).

LDEQ indicated that EWRT was used as the initial screen to identify emission sources that were believed to contribute to visibility impairment. Specifically, any facility with an SO_4 or NO_3 EWRT less than 0.05% of the domain EWRT was excluded.[9]

One significant issue with the above criteria was that LDEQ's analysis excluded a source if either the SO_4 <u>or</u> NO_3 EWRT was below the 0.05% threshold. As such, only facilities meeting the EWRT threshold for both SO_4 and NO_3 survived the initial LDEQ cut. Using the previous example of the Brame Energy Center, Brame would have been excluded from further consideration in the second-round visibility analysis based on the EWRT calculation alone.[10] At Breton Island (BRIS1), LDEQ calculated that Brame met the EWRT-only source selection criteria for NO_3, but not SO_4. On the other hand, at Caney Creek (CACR1), LDEQ calculated the opposite, and Brame met the EWRT-only source selection criteria for SO_4 but not NO_3. Yet by all accounts, Brame is among the larger emission sources for visibility precursor emissions within Louisiana and logic dictates that its emissions likely contributed to adverse visibility impacts. The outcome at Brame is just one example of how LDEQ erred by considering only the combined NO_3 and SO_4 effects. If a given emissions source had the potential to adversely impact visibility based on either the NO_3 or SO_4 impacts, it should have been carried forward by LDEQ for further analysis.

Also, serious concerns exist as to whether EWRT on its own is an appropriate criterion to identify whether or not a source may or may not contribute to visibility impairment. The EWRT is essentially a measurement of the frequency and duration as to whether an individual facility impacts the IMPROVE monitor on one or more of the 20% most impaired days. However, the EWRT by itself does not identify the possible magnitude of any single-source visibility impacts.

In the LDEQ modeling analysis, the EWRT represents the frequency/duration of time when emissions from an individual facility crossed the Class I IMPROVE monitor of interest over the sum of all of the 20% most-impaired days. However, take for example the situation where the source in question might impact the Class I area on just a few of the most-impaired days. Because the impact frequency is limited, the EWRT relative to other sources in the modeling domain would also have been small. However, the LDEQ approach failed to address the magnitude of the Class I visibility impact. For example, it could be that the source of interest has a large and pervasive adverse visibility impact on days when its emissions cross the Class I area, even if the frequency of occurrence is small. However, given that the frequency of impact is low, the EWRT relative to other sources would also be low. Under this scenario, a source might be erroneously excluded for further consideration by LDEQ, even in a situation when its emissions might be the primary contributor to adverse visibility on one or more of the 20% most-impaired days. The above provides just one example of why EWRT by itself as used by LDEQ would be a poor indicator of the potential visibility impact of a given emissions source.

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[9] LDEQ Source Selection Summary for Regional Haze Planning Period II, Page 2.

[10] LDEQ Spreadsheet: RH_PP2_SourceSelection_Version_2-1.xlsx

In its visibility calculation spreadsheet, LDEQ also provided information for EWRT weighted by emissions, using either the emissions directly (Q), or the emissions over distance ratio (Q/D) where D is the distance between the source of interest and the Class I area. The emissions-weighted EWRT would have been a much better and appropriate measure of the potential visibility effects because the emissions are related to whether the magnitude of the adverse visibility impact might be significant.

Using the same example cited above, the Brame EWRT when weighted by emissions (using either Q or Q/D) would have met the criteria established by LDEQ to identify a source as significant[11] and merit further consideration for inclusion under the "four-factor" analysis. This would have been the expected outcome for such a large source of visibility precursor emissions.

LDEQ should eliminate the EWRT criteria in its selection process as the EWRT by itself is a poor indicator of the potential visibility impact of an individual emissions source.

LDEQ Thresholds

In addition to the EWRT criteria discussed above, LDEQ established two more thresholds for identification of facilities believed to have a significant contribution to adverse visibility impairment on the 20% most impaired days at a given Class I area.[12] These thresholds are as follows:

- Using EWRT * Q/D, a source must fall within the top 75% for the cumulative EWRT * Q/D across all sources in the modeling domain.
- Any source falling in the top 75% on a cumulative basis was also evaluated and eliminated if the individual source contribution to visibility impairment was less than 1% based on the overall light extinction.

LDEQ thresholds summarized above were arbitrary and presented without sufficient justification as to why such thresholds appropriately identified emission sources that contribute to adverse visibility impairment at Class I areas. First, as explained above, the LDEQ evaluation thresholds were arbitrarily and inappropriately based on the combined visibility effects considering both NOx and SO_2 emissions. Relying solely on the combined NOx and SO_2 effects was improper and LDEQ should have identified sources as contributing to adverse visibility impairment if either the NOx or SO_2 impacts were significant. Evaluating NOx and SO_2 effects on an individual basis also would have made the LDEQ analysis more consistent with the application of emissions controls, which are applied to individual pollutants, i.e., SO_2 or NOx.

In addition, the LDEQ thresholds only evaluated the visibility impact of an individual source relative to other emission sources in the modeling domain. The thresholds as selected by LDEQ did not consider whether or not an individual source may or may not have actually contributed to adverse visibility impacts. The modeling approach selected by LDEQ likely missed important individual sources that still contributed significantly to adverse visibility impairment.

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[11] LDEQ Spreadsheet: RH_PP2_SourceSelection_Version_2-1.xlsx

[12] LDEQ Source Selection Summary for Regional Haze Planning Period II, Page 2.

For the reasons described above, plus the fact that LDEQ relied on annual emissions and not daily emissions, the LDEQ thresholds should have been set to be more inclusive with the goal of capturing a majority of the contributing emission sources. For example, the cumulative impact threshold could have been set at 90% and not 75%, thereby capturing additional sources that contribute to ongoing visibility impairment. Also, the individual source contribution threshold could have been set at 0.3% and not 1%, which would have been more consistent with thresholds selected to identify contributing sources in other CENSARA states.[13] The 1% individual source contribution threshold selected by LDEQ was also problematic given that adverse visibility impacts occur due to the cumulative effects from a large number of sources, each having a relatively small individual source contribution. The cumulative impact scenario described above in fact describes the source contribution to visibility impairment at most Class I areas across the country.

The recommended thresholds listed above would have provided for more inclusive source identification and would have better captured those emission sources that have a smaller, yet still important and significant contribution to adverse visibility impairment.

References

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[13] USEPA 2014.