RUN SPECIFICATION SHEET

DYNAMIC EVALUATION – 2002 CAMX SIMULATION AND ANALYSIS

WRAP 2014 Modeling Study
February 24, 2020

Run Name:	**Task 3: Dynamic Evaluation**
Model:	CAMx v7.0
Domains:	36US1 and 12WUS2 two-way nesting (see Figure 1)
Period:	2014 annual period
Emissions:	2002 Backcast Emissions Inventory
Boundary Conditions:	WRAP Revised 2014 GEOS-Chem Base Case
Source Apportionment:	None
Purpose:	To evaluate the visibility projection procedures by comparing modeled and observed visibility impairment on the Most Impaired Days (MID) between the 2000-2004 Baseline and 2014-2018 5-Year planning period. Also used to evaluate U.S. anthropogenic emissions contributions to visibility impairment between the 2002 past, current and 2028 future years.

DESCRIPTION

EPA's ozone, $PM_{2.5}$ and regional haze modeling guidance (EPA, 2018[1]) identifies four types of model performance evaluation (MPE) for a photochemical grid model (PGM):

- Operational Evaluation that evaluates the model's ability to reproduce concurrent observations for the base modeling year;
- Diagnostic Evaluation that is a process-oriented evaluation that evaluates the model's ability to reproduce observed meteorological, chemical and physical processes that lead to the air quality issues being examined;
- Dynamic Evaluation that evaluates the model's ability to correctly simulate the changes in concentrations/visibility in response to changes in emissions; and
- Probabilistic Evaluation that attempts to assess the level of confidence in the model predictions through techniques such as ensemble model simulations.

The WRAP 2014 Study is conducting an Operational and Diagnostic Evaluation of the PGM 2014v1[2] and 2014v2 base case simulations. This document describes the 2002 PGM simulation that will be used in a Dynamic Evaluation. The first step of the Dynamic Evaluation is to backcast the 2014v2 U.S. anthropogenic emissions to the year 2002. A CAMx 2002 simulation will be conducted using 2014 meteorological inputs and the modeled changes in visibility from 2002 to current conditions (2014-2018) will be compared against the observed

[1] https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf
[2] http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

changes in visibility from the 2000-2004 5-year Baseline to the 2014-2018 5-year planning period to determine how well the WRAP 2014 modeling platform and visibility projection procedures predict the observed changes in visibility in response to changes in U.S. anthropogenic emissions over time. Ultimately, the Dynamic Evaluation 2002 CAMx simulation will also be used to compare the changes in U.S. anthropogenic contributions to visibility impairment at Class I Areas (CIAs) over time for the 2000-2004 Baseline, the 2014-2018 current Representative Baseline (RepBase) and 2028 future year periods to help assess progress in reducing U.S. man-made contributions to visibility impairment at CIAs. The approach for this Dynamic Evaluation was summarized in a Scoping Analysis document dated December 10, 2019.

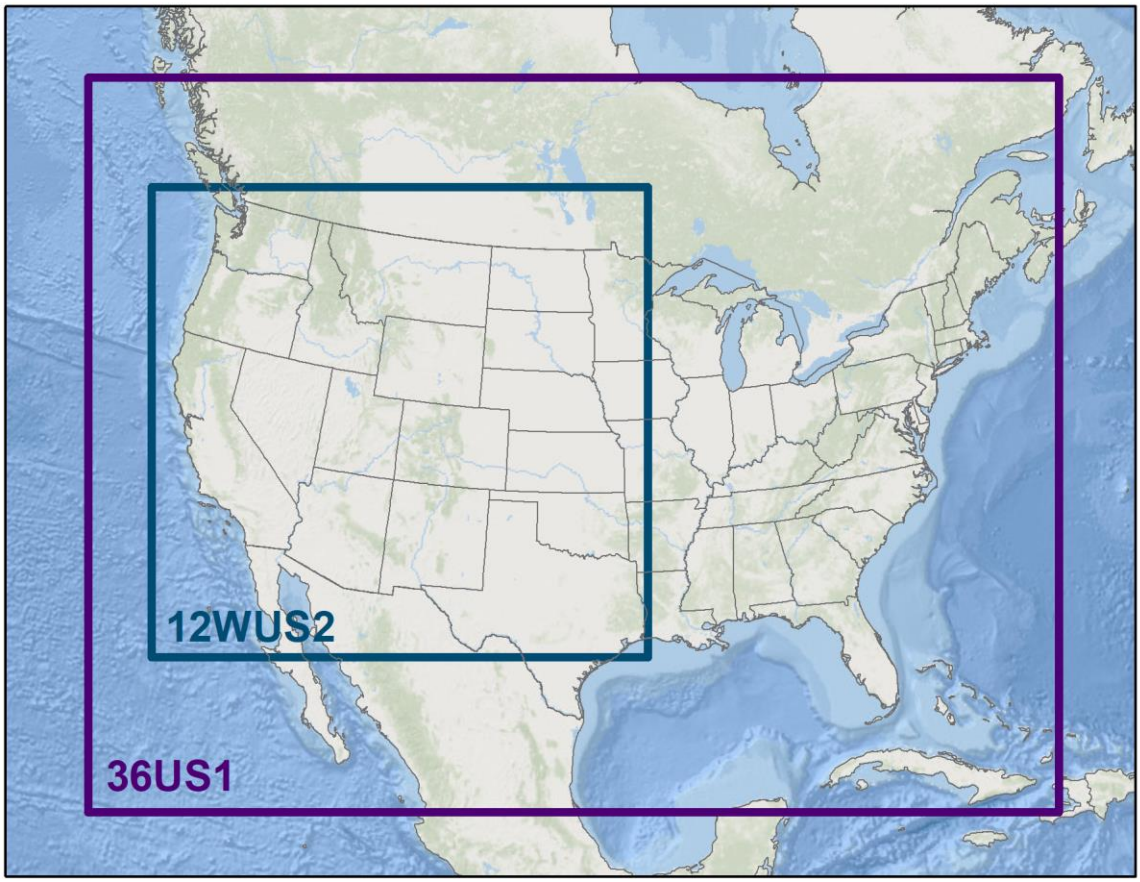

Figure 1. WRAP/WAQS 36/12-km 36US/12WUS2 modeling domains used in the WRAP 2014v2, RepBase and 2028OTB CAMx simulations.

SOURCE APPORTIONMENT SPECIFICATIONS

A source apportionment simulation using the 2002 emissions scenario is not currently planned. However, since the Dynamic Evaluation 2002 and RepBase CAMx simulations use the same natural and non-U.S. anthropogenic emissions and BCs, the Task 1.8 RepBase source apportionment simulation will be used to back-out PM concentrations due to these sources in the 2002 CAMx simulation leaving an estimate of the 2002 U.S. anthropogenic

emissions contributions to PM concentrations from which U.S. anthropogenic visibility impairment can be calculated.

EMISSIONS

The 2014v2 U.S. anthropogenic emissions will be backcast to 2002 using similar procedures as used by Nopmongcol and co-workers (2017)[3]. Details on these procedures for the WRAP 2002 Dynamic Evaluation are contained in a Memorandum (Alvarez, Shah and Morris, 2020) with a summary provided below. State-specific 2014 to 2002 backcast scaling factors will be developed for each species (i.e., VOC, NO_X, SO_2, CO, NH_3, $PM_{2.5}$ and PM_{10}) mainly using 2002/2014 scaling factors based on the latest EPA's National Emissions Inventory (NEI) trends data[4], except for a few special cases as discussed below.

Mapping of EPA's Trends Tier 1 Categories to 2014v2 Model-Ready Emission Source Sectors

EPA currently has state-specific trends for 13 Tier 1 anthropogenic emission categories available for years 1990-2017. The scaling factors will be used to backcast the source sector-specific model-ready 2014v2 emissions (i.e., pre-merged emissions) for the 36-km 36US1 and 12-km 12WUS2 modeling domains shown in Figure 1.

The model-ready emissions for 2014v2 scenario are available by inventory sectors (e.g., EGU point, non-EGU point, on-road mobile, non-road engines , oil and gas, non-point, etc.), while EPA NEI trend emissions are summarized by SCC Tier 1 categories. The Tier 1 categories do not match one-to-one to the pre-merged model-ready emission sector categories. Therefore, a mapping by state was developed from the WRAP 2014v2 inventory to be able to apply the NEI trends changes in emission between 2014 and 2002 to sector groupings (i.e. model-ready categories).

Once emissions for the NEI trends are mapped from Tier 1 to model-ready sectors, the state-specific 2014 to 2002 backcast scaling factors are developed for each species (i.e., VOC, NO_X, SO_2, CO, NH_3, $PM_{2.5}$ and PM_{10}) for the conterminous U.S. except California. Figures 2 and 3 display examples of 2002/2014 scalers for the non-point and non-road mobile source sectors, respectively for NO_X, VOC, PM_{10} and CO based on the NEI trends and for WRAP states. For most source sectors, the scaling factors are directly based on emissions ratio of 2002/2014 from the NEI trends (i.e. no further modification aside from mapping).

[3] Nopmongcol U., Alvarez Y., Jung J., Grant J., Kumar N., Yarwood G. 2017. Source contributions to United States ozone and particulate matter over five decades from 1970 to 2020. Atmospheric Environment. 167, 116-128, doi: 10.1016/j.atmosenv.2017.08.009.

[4] https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

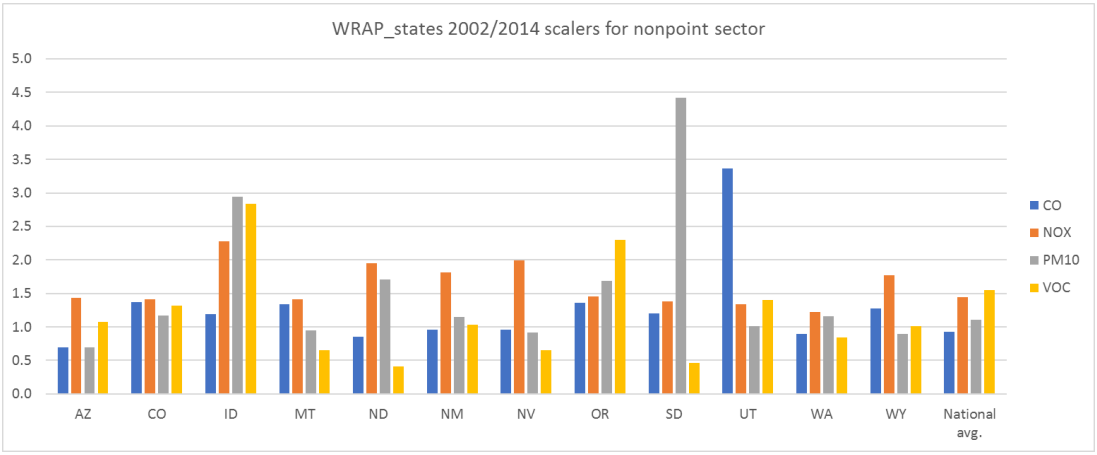

Figure 2. 2002 to 2014 emission scalers for the nonpoint sector based on NEI Trends for WRAP States

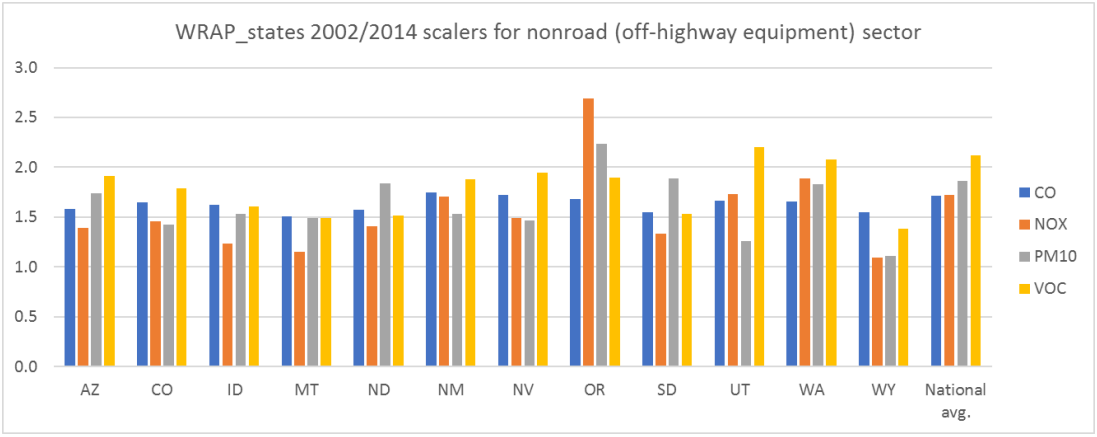

Figure 3. 2002 to 2014 emission scalers for the off-highway (non-road mobile) sector based on NEI Trends for WRAP States

Exceptions to Using the NEI Trends Scaling Factors to Backcast 2014 to 2002

Based on the availability of emissions inventories developed specifically for certain sectors of the WRAP region and inadequacies in the EPA NEI trends data, special methodologies were used to generate 2002 emissions for several source categories of anthropogenic emissions in the WRAP states as follows:

- California Emissions
- EGU Point and non-EGU Point sources for the WRAP states
- Oil and Gas Emissions for WRAP States

In addition, Boundary Conditions (BCs) and several emission source categories within the 36/12-km domains (Figure 1) were held constant at RepBase levels:

- Fire Emissions (RepBase fires; WF, Rx and Ag).
- Natural Emissions (i.e., biogenic, lightning NOx, oceanic and WBD).
- Mexico and Canada anthropogenic emissions.

Electrical Generating Units and Industrial Point Source Emissions

Emissions for Electrical Generating Units (EGUs) with Continuous Emissions Monitoring (CEM) devices, along with other non-CEM EGUs and large industrial point sources (i.e.., the ptegu and ptnonipm model-ready source sectors), were compiled by WRAP for calendar year 2002 and the WRAP states during the first round of regional haze modeling. The 2002 planning inventory version d (Plan02d) point source emissions are available in "Pivot Tables" on the archived WRAP website [5].

We compared the total WRAP state 2002 EGU and non-EGU point source emissions from the Plan02d Pivot Tables to equivalent emissions from the NEI trends for the WRAP region (except California, Alaska and Hawaii) that is shown in Table 1. The comparison shows that NO_X and SO_2 emissions across the WRAP region are very close (NO_X within 4% and SO_2 within 0%) between the two datasets for EGU sources. The Plan02d dataset EGU VOC and CO estimates are larger than NEI trends. For PM_{10} and $PM_{2.5}$, WRAP 2002 EGU compilation appears to have lower values. For non-EGU point sources, the agreement between the 2002 NEI trends and WRAP 2002 inventories across the WRAP states is not as good: NO_X within 34% and SO_2 within 5%. Because the WRAP Plan02d inventory was compiled as a bottom-up emission inventory using state data, it is likely higher quality than the NEI Trends date for 2002 so we will use this dataset as the 2002 EGU and non-EGU point source emissions for WRAP region. We will process the WRAP Plan02d Pivot Table point source emissions through SMOKE for the WRAP states. For non-WRAP states, the 2014v2 ptegu and ptnonipm emissions will be scaled using the NEI trends as it is done for other sectors described above.

[5] https://www.wrapair.org/forums/ssjf/pivot.html

Table 1. Comparison of 2002 Point emissions for WRAP region (except California, Alaska and Hawaii) between Plan02d Pivot Tables and NEI trends.

	% difference [(Plan02d - NEI)/NEI]						
Model-ready categories	**CO**	**NH_3**	**NO_X**	**PM_{10}**	**PM_{25}**	**SO_2**	**VOC**
Pt-EGU Total	28%	46%	4%	-36%	-59%	0%	45%
Pt-nonipm (non-EGU) Total	16%	-33%	34%	-21%	-57%	5%	48%
TOTAL	18%	-16%	11%	-26%	-58%	1%	47%

Treatment of California Emissions

The California Air Resources Board (ARB) provided a complete California anthropogenic emissions inventory for the WRAP 2014v2 emissions scenario that was also used in the RepBase emissions scenario. The ARB has its own emissions trends database for each year from 2000 to 2035 on its CEPAM Tool website.[6] The ARB CEPAM database breaks down emissions into 76 different anthropogenic emissions source sectors so is much more refined than the NEI trends database Tier 1 categories making it easier to match with the pre-merged emissions source sectors. The 76 categories in the CEPAM inventory were mapped to the model-ready 2014v2 CARB categories to develop 2014 to 2002 sector scaling factors that were used to adjust the California pre-merged 2014v2 emissions to 2002 levels.

Oil and Gas Emissions for WRAP States

For the WRAP states, we incorporated data from emission inventories available for the region in order to backcast emissions to 2002. In 2007, Ramboll (then ENVIRON) prepared a 2002 oil and gas area source emissions inventory[7] based on local activity and control strategies for WRAP States. We compared the 2002 O&G emission estimates from the NEI trends database for non-point oil and gas sector with the WRAP 2002 bottom-up emissions inventory and found that the NEI trends 2002 O&G emissions had much lower NOx emissions than 2002 WRAP O&G inventory, as shown in Table 2. For example, the total non-point O&G NO_X emissions in Colorado from the WRAP 2002 inventory was 23,518 tons per year (tpy), whereas the EPA NEI trends database only had 597 tpy. The NEI trends 2002 O&G emissions are clearly incorrect, so we are using the WRAP 2002 O&G inventory combined with 2014 WRAP 2014v2 emissions to develop backcasting scaling factors, as the WRAP "bottom up" 2002 inventories were developed specifically for the region and are higher quality than the EPA Trends 2002 O&G emissions.

[6] https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

[7] Environ, 2002. WRAP Area Source Emissions Inventory Projections and Control Strategy Evaluation Phase II. September. Available at: https://www.wrapair.org/forums/ogwg/documents/2007-10_Phase_II_O&G_Final)Report(v10-07%20rev.s).pdf

Table 2. Comparison of 2002 NOx emissions of nonpoint oil and gas sector from the WRAP 2007 Study and NEI Trends and Sample 2002/2014 scalers for WRAP States

	2002 WRAP EI (2007 Study)	NEI Trends (2002)	x difference [WRAP = xNEI]	WRAP-based 2002/2014 Scaler
State	NOx (tpy)	NOx (tpy)		NOx
AK	886	426	2.1	0.38
AZ	17	7	2.4	1.15
CO	23,518	597	39.4	0.67
ID	0	0		
MT	7,557	488	15.5	1.62
NV	62	24	2.6	5.73
NM	55,640	738	75.4	1.23
ND	4,631	10	477.6	0.11
OR	85	1	94.3	2.60
SD	361	0		0.74
UT	3,335	469	7.1	1.81
WA	0	0		
WY	14,725	2,954	5.0	0.44

On-Road Mobile Source Emissions

We evaluated the EPA NEI trends estimates for on-road mobile sources between 2014 and 2002 by comparing them with MOVES2014b model[8] simulations using state default assumptions. We conducted this test for the states of Arizona, Colorado and Washington as they are three of the non-California WRAP states with high population centers (i.e., mobile source contributions) near Class I areas. We found that differences between datasets appear reasonable considering that NEI trend emissions are likely to include some state-level input data such as regional fuel specifications that may affect SO_2 and PM_{10}. Moreover, NEI trend documentation notes that 2002 and 2014 emissions have been recently updated and use the latest MOVES2014 model[9]. Therefore, we are using the NEI trends highway vehicle emissions to develop scalers for on-road mobile source sector for all U.S. states.

USES OF DYNAMIC EVALUATION 2002 CAMX SIMULATION

There are two main uses of the CAMx 2002 simulation: (1) conduct a Dynamic Evaluation that compares the observed changes in visibility for the Most Impaired Days (MID) between the 2000-2004 5-year Baseline period and the 2014-2018 5-year planning period with the modeled changes using the same procedures for making 2028 visibility projections; and (2) calculate the changes in visibility due to U.S. anthropogenic emissions from the 2002 past year to the current year RepBase conditions and to the 2028 future year to help assess progress towards toward natural conditions (i.e., no U.S. man-made impairment) in 2064.

[8] https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

[9] " Highway and Off-Highway emissions were updated for 2002, 2005, 2007, 2009 and 2010. 2015 & 2016 mobile emissions were calculated through interpolation using the 2017 onroad/nonroad modeling file […] This update will produce noticeable changes in emissions from 2001 to 2002". README tab of https://www.epa.gov/sites/production/files/2018-07/state_tier1_caps.xlsx

Dynamic Evaluation

Observed Changes in Visibility between Past and Current Years

The latest (December 2019) updated IMPROVE database with new MID definitions will be used to characterize the observed visibility impairment for the 2000-2004 5-year Baseline and 2014-2018 5-year planning period.

2028 Visibility Projection Techniques

WRAP is making 2028 visibility projections several different ways using the CAMx modeling results from the RepBase and 2028OTBa emission scenarios. The EPA recommended approach (EPA, 2018) is to develop species-specific Relative Response Factors (RRFs) using the ratio of model estimates from the future (2028) to the current (RepBase) simulation averaged across the days in the MID for the base modeling year (2014 in this case). The RRFs are applied to the observed PM species concentrations for the IMPROVE MID from the 2014-2018 5-year planning period and then averaged for each year and across all 5-years to obtain 2028 visibility projections for the MID. The IMPROVE MID are estimated to be the 20% most impaired days by anthropogenic emissions so have been selected to minimize the influence of fires and windblown dust natural events. However, the model may have wildfire impacts on the IMPROVE 2014 MID that would produce stiff RRFs and underestimate 2028 future year visibility improvements. Thus, WRAP will make 2028 visibility projections using the CAMx RepBase and 2028OTBa modeling results several ways:

1. EPA RRFs that are based on the average of modeled concentrations across the 2014 IMPROVE MID following EPA guidance (EPA, 2018).
2. Modified EPA RRFs that are based on the average of modeled concentrations across the 2014 IMPROVE MID excluding days in which the RepBase CAMx simulation has obvious fire impacts.
3. RRFs based on modeled MID that use the Task 1.8 RepBase source apportionment simulation to determine the 20% of days at an IMPROVE site that have the most U.S. anthropogenic emissions impairment.

Dynamic Evaluation Comparison

The CAMx RepBase and 2002 modeling results (RRF = $CAMx_{2002}/CAMx_{RepBase}$) would be used to backcast the observed IMPROVE MID for the 2014-2018 5-year planning period to 2002 using the three sets of RRFs discussed above. The modeled backcast 2002 visibility impairment for the MID would be compared against the observed 2000-2004 IMPROVE MID visibility impairment in a Dynamic Evaluation.

The CAMx 2002 and RepBase modeling results (RRF = $CAMx_{RepBase}/CAMx_{2002}$) will be used to project the observed IMPROVE 2000-2004 MID to 2014-2018 RepBase conditions using the three sets of RRFs listed above. A fourth RRF based on the modeled MID in the CAMx 2002 simulation could also be used as the 20% MID would be expected to change over time even for the same meteorological conditions (e.g., days dominated by sulfate in 2002 may drop out of the 20% MID in 2014).

Trends in U.S. Anthropogenic Emissions Visibility Impairment

The Task 1.8 RepBase Source Apportionment (SA) simulation will be used to estimate the amount of visibility impairment that is due to U.S. anthropogenic emissions for each modeling day and IMPROVE site. The RepBase SA simulation provides an estimate of U.S. anthropogenic emissions visibility impairment under current (2014-2018) conditions.

The RepBase SA simulation uses the same BCs, natural emissions and Mexico and Canada anthropogenic emissions as the CAMx 2002 Dynamic Evaluation simulation so that the two simulations only differ by U.S. anthropogenic emissions. The RepBase SA modeling results will be used to back-out the non-U.S. anthropogenic contributions from the 2002 CAMx simulation for each modeling day and IMPROVE site leaving an estimate of the 2002 U.S. anthropogenic emissions contribution from which visibility impairment can be calculated for each day and IMPROVE site.

Under Task 4.7 we plan on conducting a CAMx source apportionment simulation for the 2028OTBa future year emissions scenario that will be post-processed to provide the contributions of 2028 U.S. anthropogenic emissions to visibility impairment for each modeling day and IMPROVE site.

The above provides the U.S. anthropogenic emissions contribution to visibility impairment for each day of the 2014 calendar year and each IMPROVE site for the 2002 past year, current (2014-2018) RepBase year and 2028 future year from which trends in visibility due to U.S. anthropogenic emissions can be calculated for various groups of days, such as:

- Annual average.
- IMPROVE 2014 MID.
- IMPROVE 2014 MID with days with modeled fire impacts eliminated.
- Modeled RepBase MID.