CAST-2019 Release

Changes between the CAST-2017d and CAST-2019 versions

- **Updates may increase or decrease the loads in all scenarios.**
- The 2013 – 2025 land use acres and septic systems changed with updates to the following.
  - Updated 2025 Current Zoning land use to use new data for population projections, protected lands, sewer service areas, and agricultural lands. The agricultural land use acres are determined by the National Agricultural Statistical Service's Agricultural Census crop and animal data.
  - Updated sewer service areas for 51 local jurisdictions to use new data for the population on sewer and septic systems for 2013 through 2025
  - Updated MS4 area for 19 local jurisdictions in Virginia. **Loads from the MS4 load sources may increase or decrease in the 19 local jurisdictions in Virginia because of the change in area.**
- 2017 Agriculture Census data was incorporated into the land use; crop, hay and pasture acres; crop yields; and animal numbers. The data between years 2013 and 2017 is now interpolated and years 2018 to 2025 are projected.
  - This information is used in producing the new 2013 – 2025 current zoning land use.
  - Consistent with CAST-2017, animal numbers are forecast at the state scale. State numbers are then proportioned to individual counties according to latest Census of Agriculture. The animal numbers are used to calculate the feeding space acres, so these will change for years 2013 through 2025. **This update will increase or decrease animal manure nutrients related to the degree of the change:**
    - **Increases in animal manure nutrients can be offset by BMPs, changes in crop types the manure is applied to, and less chemical fertilizer use.**
    - **Decreases in animal manure nutrients, generally, reduce loads.**
  - Crops are forecast by crop categories at the county scale. Categories are then proportioned to individual land use types according to latest Census of Agriculture. **This update will increase or decrease nutrient and sediment loads related to the degree of the change and, primarily, the crop nutrient needs.**
  - Agricultural fertilizer sales data for 2013 and 2014 are incorporated into the model. **The crop need will change for all scenarios. This update will increase or decrease loads depending on the change in crop need from CAST-2017.**
- The application rates on urban turfgrass changed for years between 2013 and 2025 because the urban acreage changed. In addition, there is an additional year of urban fertilizer sales data. These updates will change the loads on developed pervious load sources.
- **Recalculated wastewater for the annual progress scenarios may increase loads for progress years 1984-2015 in which upgrades occurred in the second half of the year. There is no effect on calibration or WIPs.**
  - Wastewater data is aggregated by calendar year for VA in all years and by calendar year for DC through 2017. For all other jurisdictions and in DC after 2017, wastewater is aggregated by the year of July 1 to June 30. In the CAST-2017 version, wastewater was

aggregated by calendar year for all jurisdictions through 2015 for the annual progress scenarios.

- **BMP costs change due to updates and corrections.** *Note: This change is not available in the CAST-2019 beta version.*
  - Corrections were made to the annualization cost formula that will change the estimated costs. The change only affects annual BMPs. The corrected formula is:
    - Where lifespan = 1 year, $Capital \times \left(\frac{0.05}{((1.05^{lifespan-1})}\right) + 0.05 + (Operations\ and\ Maintenance) + (Opportunity \times 0.05)$
  - BMP costs were updated with recent literature values and use 2018 dollars.
- The full crediting of biofilters is now included. In CAST-2017, only partial crediting was received. The edge-of-tide loads reflect an additional load change. **This update will change loads in some WIP scenarios.**
- Stream bed and bank loads are now calculated by land-river segment and agency. **Scenarios for any given agency will be more consistent. There are no changes in delivered overall loads from land-river segments or load sources. There are small changes in total land-river segment stream loads for agencies.**
  - CAST-2017 calculated Stream bed and bank loads for all load sources and agencies. Using this method, the stream bed and bank load attributed to a federal agency would change when a scenario is run with changes in the non-federal portion. Now the load is calculated separately for each agency using all load sources.
- The nitrogen fixation rate for "other haylage; grass silage and green chop" was adjusted. **The new fixation rate will reduce total delivered nitrogen loads by approximately 0.7 million pounds in the 2018 progress scenario.**
  - This crop type had zero acres in 1995 so there would be no change to the loads during the TMDL critical period. The update is a more accurate representation of the crop's nitrogen fixation.
  - Old = 175.73 N lbs. fixed per acre; New = 30.24 N lbs. fixed per acre
- BMPs that were planning are now official. Planning BMPs include Land Policy and other BMPs that are not accepted for reporting Bay TMDL progress. Official BMPs include only those BMPs that have been approved by the Chesapeake Bay Program.
  - Agricultural Stormwater Management
  - Conservation Landscaping Practices
  - Septic Effluent - Advanced
  - Septic Secondary Treatment - Advanced
  - Septic Denitrification - Advanced
- Nitrogen fixation inputs were not accounted for properly for over-winter crops in CAST-2017. The corrected calculation in CAST-2019 now considers the change in fixation between 1995 and a scenario. **Areas and years with an increase in over-wintering crops relative to 1995 will see an appropriate increase in loads.**

Table 1. Over-wintering Crops in CAST (specific crops in double cropped load source differ by state)

State	Crop Name	Load Source
DE, MD, PA	Alfalfa hay	Double Cropped Land

State	Crop Name	Load Source
DE, MD, NY, PA, VA, WV	Barley for grain	Double Cropped Land
DE, MD, PA	Barley for grain	Small Grains and Grains
DE, MD, NY, PA, VA, WV	Canola	Small Grains and Grains
DE, MD, NY, PA, VA, WV	Emmer and spelt	Small Grains and Grains
DE, MD, NY, PA, WV	Orchardgrass seed	Other Hay
DE, MD, NY, PA, VA, WV	Other haylage; grass silage and greenchop	Double Cropped Land
DE, MD, NY, PA, VA, WV	Rye for grain	Double Cropped Land
DE, MD, NY, PA, VA, WV	Rye for grain	Small Grains and Grains
DE, MD	Ryegrass seed	Other Hay
DE, MD, NY, PA, VA, WV	Small grain hay	Double Cropped Land
DE, MD, NY, PA, VA, WV	Triticale	Double Cropped Land
DE, MD, NY, PA, VA, WV	Triticale	Small Grains and Grains
DE, MD, VA	Vetch seed	Leguminous Hay
DE, MD, NY, PA, VA, WV	Wheat for grain	Double Cropped Land
DE, MD, NY, PA, VA, WV	Wheat for grain	Small Grains and Grains
MD, PA	Berries - all	Specialty Crop Low
MD, NY, PA, WV	Pumpkins	Specialty Crop High
MD, NY, PA, WV	Timothy seed	Other Hay
MD, NY, PA, WV	Turnips	Specialty Crop High
NY	Sunflower seed - non-oil varieties	Specialty Crop Low
NY	Sunflower seed - oil varieties	Specialty Crop Low
VA	Red clover seed	Leguminous Hay

Accounting for changes to the BMP record during the TMDL critical period

Most changes to CAST-2019 are for future years, however some adjustments, such as the BMP history, change loads throughout the modeled history. The year 1995 is a significant date because it marks the end of the TMDL critical period, used as the starting point for load reductions necessary to meet water quality standards. To ensure CAST is measuring a change in management actions rather than a change in data, the difference between the 1995 loads in CAST-2017d and CAST-2019 for each land-river segment, load source, and agency is determined. Where the difference is greater than zero, this difference is subtracted from the CAST-2019 load for years after 1995. This adjustment allows states to update their BMP historic record and for CAST to improve with new data and scientific information.

Accounting for changes in the land use and animals

BMP Back Out

The amount of the BMP listed as not credited in the BMP Submitted vs. Credited report now uses the BMP implementation amount in the 2017 year. Years prior to 2018 use that year's information rather than 2017.

Scenarios in CAST-2017d used projected data for years after 2012. With the new data in CAST-2019, scenarios use projected data for years after 2017. In scenarios you create for any year, only the land use change BMP implementation in excess of that in the base conditions for that year are credited. The land use change is already accounted for in the base condition land, and this ensures that change is not credited twice. Where there are no annual BMPs reported, such as with a future year like 2023, then 2017 is used to assess if land use change BMPs are greater than those reported.

Nutrient Applications and Crop Nutrient Need

The nitrogen and phosphorus nutrients are applied to agricultural load sources using the fraction of crop need met in that year's progress. This calculation is done for each year, county, crop and load source, month and nutrient. The 2014 plant-available phosphorus available for application to the agricultural load sources is used for years after 2014. For years up to and including 2014, the crop need and plant-available phosphorus is calculated based on nutrients available, location of nutrients after BMPs, and crop need and uptake for that year. If the amount of crop need met in 2014 was 110%, then 110% of crop need will be met in 2015. The application rate will be even higher if Manure Transport and/or the Nutrient Management BMP was implemented in 2014 but not in later years.

When selecting base conditions for years between 1984 and 2014, the amount of crop need calculated from the ratio of all nutrient inputs applied to meet crop need are defined by the official annual progress scenario for that year.

For phosphorus, the difference between the amount of manure transport in 2014 and later years is subtracted from the amount of manure nutrients applied after other nutrients are applied to meet the proportion of crop need met in 2014. The implication is that if more manure is transported out of a location than was transported out in the 2017 Progress, the phosphorus applied is effectively lowered. Conversely, if less manure is transported out of a location than was transported out in the 2014 Progress, the phosphorus applied increases.

Developing the Watershed Model land use from the mapped land use (True Up)

The high-resolution mapped land cover data set acts as a starting point for the back casted land use using the Chesapeake Bay Land Change Data (CBLCD) and the forecasted land use using the CBLCM. This produces a consistent land use data set for select years between 1984 and 2025, however this is not the final land use data set used in the Phase 6 Watershed Model. For use in the Watershed Model, the land use must be checked for consistency, interpolated to all years, and combined with the Census of Agriculture, harvested forest acres reported by the states, and the proportion of land between regulated and non-regulated feeding space reported by the states. The steps for adjusting the mapped land use to the tabular version used in the model are described below.

Initial adjustments to the mapped land use

The first steps are to confirm that the CSS acres remain constant in the pre-BMP land use. Changes to CSS due to sewer hookups are handled in the wastewater inputs, not in the land use. Thus, they are accounted for only once. The CSS crop and pasture mapped land uses are moved to the CSS mixed open load source. The CSS forest, wetland, and water are moved to CSS forest load source.

It was decided in the Federal Facility Workgroup and approved by the Water Quality Goal Implementation Team that there would be no agricultural land attributed as federal. The federal, Maryland State, and Maryland State Highway agencies within the mapped crop and pastureland uses are moved to the nonfederal classification. In addition, the decision was made that the total area of each agency in a land-river segment remains constant. Where necessary, proportional adjustments are made for years other than 2013 such that the total for each agency in each land-river segment is the same as 2013.

The regulated and CSS construction and harvested forest acres are all considered non-federal agency types per the Federal Facility Workgroup. These areas are submitted by the states or a default is used. The harvested forest default is 1.5 percent of true forest. The construction default = 1.29 * (current year + 1 developed acre - current year's developed acres). Construction acres are taken proportionally from developed land uses. Harvest forest is taken from true forest.

As detailed in prior sections, the mapped land uses are provided for 1984, 1991, 2001, 2006, 2013, and 2025. The land use is linearly interpolated to all years 1984-2025.

For interpolation, the land-river segment total acres are set equivalent to the CBLCM 2013 total acres. Note that the GIS total acre data includes tidal wetlands, whereas the Watershed Model does not.

For Virginia, crop and pasture acres are adjusted to match the spatially explicit acres from the mapped land uses based on error rates. While agricultural land error rates originate with the Agricultural Census for all other states, in Virginia the rates are lower since those agricultural areas were spatially mapped through a more accurate process. This results in the Agricultural Census acres being closer to the mapped crop and pasture.

Maryland Adjustments to the Land Cover Data

Maryland received the land use by land-river segment, agency, and land use for 1984 to 2013. The Maryland land use data are altered with data provided by the Maryland Department of the Environment for each year. Generally, adjustments are made to developed classes. Upon return to the CBPO a proportional adjustment is made to the Maryland CSS acres to force a match to the total CSS acres for each land-river segment and agency.

Maryland did not edit CBP USGS's land-cover dataset for the following counties:

Baltimore County	Calvert County	Caroline County
Garrett County	Kent County	Somerset County
St. Mary's County	Worchester County	

For the remaining counties and Baltimore City, MDE edited the Mapped Land Use data as follows, for the developed land-cover classifications only:

1. Replace CBP Turf Grass acres with MDE calculated Turf Grass.
    a. Calculated by applying average turf to low vegetation ratios using the Chesapeake Conservancy land cover data and digitized turf data. The average turf to low vegetation ratios for individual parcel types (Residential < 2 acres, residential 2-5 acres, residential > 5 acres, commercial, etc.) were calculated from sample datasets of digitized turf grass. Ratios also vary by MS4 grouping (Large Phase I, Medium phase I, and Phase II/non-MS4s).

2. Replace CBP Impervious Road and Impervious Non-Road acres with MDE acres. MDE estimates generated using local, planimetric impervious cover data with adjustments to account for any missing feature types, e.g., sidewalks, and any temporal differences, e.g., projected to 2013 conditions if based on older imagery.
3. Remove CBP Tree Canopy Over Impervious estimates from MDE Impervious road and non-road acres proportionally. MDE road and non-road impervious surface estimates did not account for tree canopy over impervious, so to avoid double counting, these had to be removed from MDE estimates.
4. Replace CBP Tree Canopy Over Turf acres with MDE acres. MDE applied same methodology as CBP for distinguishing between forest and tree canopy over turf; however, MDE used state-specific 1 meter resolution tree canopy data developed by the University of Vermont for the entire State of Maryland rather than the Chesapeake Conservancy land-cover data.
5. MDE's urban land-cover estimates were derived in aggregate, both for federal and non-federal lands. Federally owned lands were lumped in with MDE's non-regulated urban delineation. Therefore, in order to parse out federal from non-federal lands, CBP's federal urban land-cover acres were subtracted from MDE's nonregulated urban land-cover estimates.
6. CSS acres need to be held constant throughout the model calibration. Therefore, MDE adjusted all CSS land-cover acres to match CBP CSS land-cover acres.
7. In order to account for construction acres, MDE artificially inflated all urban land-cover acres within a land-river segment proportionally. Then, once MDE's final land-cover and construction files are combined within Scenario Builder, construction acres are subtracted from the urban land-cover estimates in the same proportions that they were artificially inflated.

Adjustments to the Census of Agriculture

Virginia has 39 cities in the Chesapeake Region that have unique Federal Information Processing (FIPs) codes. The Agricultural Census does not include records for these cities; however, the mapped land use includes agricultural classes for some. These cities are assigned a fraction of Agricultural Census crop, yield, and animal data based on a neighboring county that has agricultural data. The Virginia city Agricultural Census value for each category is equal to the associated county Agricultural Census value multiplied by the ratio of relevant mapped acres in the city to relevant mapped acres in the county. For example, if a county with Agricultural Census data has 500 acres of crop and the associated Virginia city has 50 acres of crop in the mapped land use, then the city is assigned a crop fraction of 0.1 to apply to Agricultural Census values relevant to crop. The same procedure is used for all relevant Agricultural Census values including pasture acres, animal numbers, and crop yield.

Agricultural crop, pasture and animal amounts are available only at the county scale. Some counties are located partially in and partially outside of the Chesapeake Bay watershed. The amount of crop and pasture within the watershed portion of a county is determined using the fraction of crop and pasture within the watershed from the Mapped Land Use. The fraction can vary between zero and one. This fraction is calculated for each year of the Mapped Land Use and interpolated for all other years.

For states that did not supply the number of animals within the watershed portion of the county, the fraction of animals in the Chesapeake Bay Watershed is the same as the fraction of agricultural land use acres in the Chesapeake Bay Watershed in that county.

Proportioning of Ag Census

The Agricultural Census crop acres are used in the calculation of county land use acres for the following land uses: soybeans, grains with manure, silage with manure, small grains and grains, other agronomic crops, specialty crop high, specialty crop low, agricultural open space, pasture, leguminous hay, and other hay. The amount of double cropped acres is used to determine the number of acres in the double cropped land use. The double crop method is discussed in Section 5.4.1 of the Phase 6 Watershed Model documentation. The grains and silage with manure are split from the acres without manure, using the ratio discussed in Section 5.4.2 Phase 6 Watershed Model documentation. The fractions of crop and pasture that were projected through 2025 are used to split these county total acres into land-river segments.

The estimated annual extent of agricultural land uses was apportioned from the county level to land-river segments based on the relative proportion of land-river segment acres to county acres using the three classes total agriculture, pasture, or cropland. Relative proportions of total agriculture were used to allocate: Permitted Feeding Space and Non-Permitted Feeding Space. Relative proportions of pasture were used to allocate Ag Open Space, Legume Hay, Other Hay, and Pasture. Relative proportions of cropland were used for all other agricultural land uses.

The number of acres per animal is used to determine the county feeding space acres. The number of animals is based on the animal counts as described in Section 5.4.3 Phase 6 Watershed Model documentation. The animal counts originated with the Agricultural Census and are projected using methods described in Section 3. This county number is disaggregated to land-river segments assuming that the animals per land-river segment are proportional to the agricultural land use acres in each land-river segment.

Maintaining Constant Land-River Segment Size

Once apportioned to land-river segments, the annualized Census of Agriculture agricultural land use acreages are combined with the Mapped Land Use acres for each year from 1985 – 2013. The Mapped Land Use categories of pasture and cropland are combined, and the Census of Agriculture is used to determine the individual land uses that are categorized as pasture or crop. Generally, the sum of Agricultural Census-based land use acres and mapped natural and developed acres did not match the total area of the land-river segment from the Mapped Land Use. To maintain a constant land-river segment size through time, all land uses were adjusted using relative error rates in a 'true-up' process. Land uses with high error were adjusted a greater percentage than land uses with a low error rate.

The true-up process began by comparing the total acreage in the land-river segment to the total of all the land use acreages assigned to that land-river segment. Then, the error rate for each land use was multiplied by the estimated acres of that land use to arrive at an available adjustment for each land use type. An adjustment fraction was calculated by dividing the total necessary acreage adjustment by the sum of the available adjustment. The available adjustment multiplied by the adjustment fraction for each land use was then subtracted from the land use acres to arrive at the final land use acreage in the land-river segment. To illustrate the method, suppose a land-river segment of 100 acres had only three land uses that were estimated as 15 acres of CSS roads, 50 acres of mixed open, and 50 acres of pasture. Note that the total of the land uses is 15 acres above the available acres in the land-river segment.

Assume that the error rate is 0% for CSS roads, 5% for mixed open and 10% for pasture. Available adjustment is 0 acres for CSS roads, 2.5 acres for mixed open and 5 acres for pasture. The total adjustment needed is 15 acres and the available adjustment totals 7.5 acres giving an adjustment ratio of 2. The final acres would be 15 acres of CSS roads, 45 acres of mixed open, and 40 acres of pasture.

In general, mapped land uses were adjusted according to their state-wide mapping accuracies and Census of Agriculture acreages were adjusted based on their county-level reporting standard error rates. The mapped land use accuracies apply to 2013 conditions and not necessarily to historic conditions because the back-cast process introduces additional errors. Therefore, the mapped error rates used in this "true up" process were adjusted for historic years depending on if the reported acreages in the Census of Agriculture exceeded the mapped acreages, representing a "space-constrained scenario", or if the reported acreages were less than the mapped acreages, representing an "unconstrained scenario". For the space-constrained scenario, the mapped error rates for 1985 were assumed to be the lesser of the 2013 error rates or 85 percent. For the unconstrained scenario, the mapped error rates were held constant through time except for mixed open which was given the same error rates as reported in the 2012 Census of Agriculture. For the Census reported acreages, the 2012 Census of Agriculture reporting standard errors were applied to all historic years. The 2017 Census of Agriculture calculated error rates differently, so the decision was made to use the 2012 Census of Agriculture error rates. This is consistent with the decision to use the 2012 rates for 1985 through 2012.

These error rates are used for all years. In CAST-2017d, error rates for years after 2013 were set to zero for developed and natural, except for open space. The open space error rate is equivalent to the agricultural error rate from the Agricultural Census.

The rationale for using a different approach for the unconstrained scenario is illustrated in the following example. Suppose that there should be 1,000 acres of cropland in a land-river segment according to the Census of Agriculture, but the mapped acreage is 1,500 acres. There is high confidence that the surplus 500 acres is composed of pervious herbaceous vegetation, but lower confidence that it's all agriculture. Therefore, it would be inappropriate to expand mapped roads, buildings, and forests by any significant amount into this known herbaceous area. Rather, it would be better to assume that the Census of Agriculture must have underestimated the extent of agriculture and the extent of mixed open was underestimated to the same degree. In the true-up process, mixed open, pasture, and cropland would be expanded up to, but not exceeding, the limits of the Census of Agriculture reporting error rates. The CSS and feeding space acres have an error rate of zero so do not ever change.

Following the error-based true-up process, it was found that a few land-river segments had developed land uses that decreased in a few years. It was determined that this was a fatal flaw and so the following algorithm was implemented. Starting with 2013 as the year of least uncertainty and working backwards for each land-river segment, the prior year is compared to the current year. If the prior year has a higher total developed area, the developed land uses for the prior year are lowered proportionally such that the total matches the current year. The total subtracted acres are added proportionately to the mixed open and hay/pastureland classes as these classes are most likely to be confused with turfgrass.

Projecting 2014 – 2025 CBLCM Land Use

The next step is to create a baseline used for projecting the land use. This baseline is the 2013 pre-BMP land use without Maryland's 2013 adjustments and the MS4-permitted acres. A change factor is multiplied by this 2013 baseline to generate a 2025 projected land use. The change factor is calculated as the percent change in the Mapped Land Use between 2013 and 2025 for each land-river segment and agency. Then the actual 2013 and the 2025 land use are interpolated to create the interim data product of a 2014 to 2024 land use. The steps described above are followed for creating the final 2014 through 2025.