Maryland *Draft* Impervious Calculation Methodology
(GIS Processing Methods - 2012 Model Year)

Contents

Overview

Maryland developed tabular estimates of impervious surface (for both road and non-road impervious) by Chesapeake Bay Program (CBP) Phase 6 land-river segment for the 2012 model year. These methods were developed by Maryland Department of the Environment (MDE) and Maryland Department of Planning (MDP). Planimetric impervious cover data from Maryland's local jurisdictions were the primary data source for these estimates. NAVTEQ roads data were used when necessary to determine the road portion of the impervious data. Local high resolution land use data were used to supplement when available. When planimetric data were not available, CBP regional estimates were used. This document functions as technical documentation of the Geographical Information System (GIS) methods followed to standardize methods and ensure quality. This was not intended as a broad overview of tabular impervious surface methodology.

General

Projection/Datum: Ensure all data have the same projection – NAD_1983_StatePlane_Maryland_FIPS, Lambert_Conformal_Conic (units – meters). Use 'CBP_P532_Model_Segments.shp' in segmentation folder to reproject if necessary.

Data organization: Shapefiles were named in sequential order by processing step using a standard naming convention. Output files were saved as text files for each intermediate output and reflect shapefile naming.

Quality Assurance: Each calculation included quality assurance checks by experienced GIS staff who have been trained in implementing the methods described in this document. Each step was repeated or validated and the transfer and calculations in Excel were verified. An additional final round of systematic quality assurance checks were performed to account for any tabulation or summarization errors. Each calculation Excel file was compared to the original output text files and a systematic check of formulas included in each Excel sheet was performed.

Of 24 counties in Maryland (including Baltimore City), planimetric data were able to inform impervious area estimates for 19 counties. No data were available for Garrett, Somerset, St. Mary's, Washington, or Worcester counties. The table below lists the 19 counties, the imagery year of the impervious dataset, and the method used to estimate 2012 impervious area by land river segment. Counties are listed in order by method. Five counties had complete planimetric data available, while the other 14 were missing a portion of the impervious data which was generally accounted for using missing feature coefficients. A combined high-resolution raster land-cover dataset along with available planimetric data was used to account for missing impervious features in Baltimore County. Each method is described in more detail in the sections that follow.

#	County	Impervious Data year	Method
1	Anne Arundel	2011	Complete Planimetric
2	Calvert	2011	Complete Planimetric
3	Dorchester	2010	Complete Planimetric
4	Harford	2011	Complete Planimetric
5	Prince George's	2009	Complete Planimetric
6	Baltimore County	2008	Combined raster land-cover and planimetric data to account for missing features
7	Allegany	2005	Incomplete - missing patios, recreational features, pools, all sidewalks
8	Baltimore City	2008	Incomplete - missing patios, secondary sidewalks
9	Caroline	2008	Incomplete - missing patios, pools, all sidewalks
10	Carroll	2014	Incomplete - missing patios, pools, secondary sidewalks
11	Cecil	2013	Incomplete – missing patios, pools, recreational features, all sidewalks, driveways, and parking lots
12	Charles	2011	Incomplete - missing patios <200 ft^2, driveways < 100 ft long, and secondary sidewalks
13	Frederick	2005	Incomplete - missing patios, pools, recreational features, and secondary sidewalks

#	County	Impervious Data year	Method
14	Howard	2013	Incomplete – missing buildings < 200 ft^2, patios, recreational features, and secondary sidewalks
15	Kent	2004	Incomplete – missing patios, pools, recreational features, all sidewalks, driveways, and parking lots
16	Montgomery	2010	Incomplete – Inside municipalities missing patios, pools, secondary sidewalks, and driveways. Outside municipalities missing secondary sidewalks. County data inconsistently captured patios, so this is an underestimate.
17	Queen Anne's	2008	Incomplete – partially missing patios, driveways, and secondary sidewalks outside of growth areas. Complete planimetric inside growth areas.
18	Talbot	2010	Incomplete – missing patios, recreational features, all sidewalks
19	Wicomico	2013 planimetric 2006 roads	Incomplete – Inside Salisbury missing sidewalks. Outside Salisbury missing sidewalks and parking areas.

Complete Planimetric Dataset Methods

Anne Arundel County, Calvert County, Dorchester County (feature type not specified), Harford County (feature type not specified), and Prince George's County

Baseline Impervious Area

Planimetric impervious data were used to determine baseline impervious area per segment. Baseline impervious area is calculated using the imagery year of the planimetric data. For instance, Anne Arundel County planimetric data were based on 2011 leaf-off orthoimagery, so the baseline development year was considered to be 2010 – all of the development built through the 2010 were considered as already included in the planimetric data. Then projections are used to predict residential, non-residential, and road impervious growth since the baseline year (e.g., 2011-2012). A correction factor is used to account for properties MDP data indicates were built since to the baseline year, but were already captured in the planimetric data to ensure projections are not double-counting already constructed buildings.

1. Compare MD State Highway Administration (SHA) impervious data to county impervious data. If no large features are missing from the SHA data only use county impervious. Include a screen capture of these data to show coverage in the Excel calculation file. If major roads are missing determine if data should be merge with SHA data (never occurred).
2. **OUTPUT 1** - Extract county specific landrivsegments into a separate shapefile specific to the county of interest using the 'CountyName' field. Export the resulting table as a text file.
3. **Intersect** impervious data layer with the county-specific landrivsegments layer to get impervious area per segment.
4. **Dissolve** by the FIDs of the segment table.
5. **OUTPUT 2** - Add new column to resulting table (tt_acre), double. **Calculate geometry** (acres). Export resulting table as a text file.
6. *EXCEL:* Add a list of segments to the 'Results' tab from OUTPUT 1. Use OUTPUT 2 to populate the impervious acres by segment in the baseline year in the 'Results' tab.

Residential Development Projection

Residential development through baseline year

1. From MDP County Parcel Points file, **select by attributes** single family residential parcels through the baseline year including residential land uses (residential = R, townhomes = TH, condos = U, Ag = A) less than or equal to 20 acres and improved area greater than or equal to 10,000 using this query:

   "YEARBlT" <= 'XXXX' AND ("LU" = 'A' OR "LU" = 'R' OR "LU" = 'TH' OR "LU" = 'U') AND "ACRES" <= 20 AND "NFMIMPVL" >=10000

   a. *Change years in formula to the year prior to the imagery – best estimate of the parcels present when the imagery was taken (e.g., impervious data year 2008, use 2007).*
2. **Export data** to create a new shapefile with these selected records.
3. **Join** new point shapefile to MDP parcel polygons using the "ACCTID" field. Keep only matching records. This will select only those polygons that correspond to the ACCTIDs of the selected points layer.
4. **Intersect** the joined layer with the MDP generalized zoning data layer.
5. **Dissolve** by parcel type ("LUClass") and zoning class ("GENZONE").
6. **OUTPUT 3** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.

Impervious Data and Residential development through baseline year

7. Impervious data – may need to **merge** data depending upon county, **dissolve** if possible, but in some cases too many records are included so an error will result.
8. **Intersect** impervious data layer with parcel_zoning_intersect_dissolve table from step 6 above. Only dissolve by FID of the step 6 table to minimize processing time and allow the next step of dissolving to function more efficiently.
9. **Dissolve** by FID of the output table of the previous step.
10. **OUTPUT 4** - **Calculate geometry** (acres) for the portion that intersects. Export resulting table as a text file to the output folder.
11. *EXCEL:* Calculate the ratio of the acreage from OUTPUT 3 to OUTPUT 4 – to develop an impervious coefficient per parcel type/zoning type.

Residential development since baseline year (bridging gap from impervious data baseline year through 2012)

12. **Select by attributes** single family residential parcels from Parcel Point data using the following query:

    ("YEARBLT" *> 'XXXX' AND* "YEARBLT" *<= '2012')* AND ("LU" = 'A' OR "LU" = 'R' OR "LU" = 'TH' OR "LU" = 'U') AND "ACRES" <= 20 AND "NFMIMPVL" >=10000

    a. *Change years in formula to the year prior to the imagery. This represent the parcels built since the impervious data layer was developed (e.g., impervious data year = 2008, use 2007).*
13. **Export data** to create a new shapefile with these selected records.

14. **Join** new point shapefile to parcel polygons using the "ACCTID" field. Keep only those that match. This will select only those polygons that correspond to the "ACCTIDs" of the selected points layer (be sure to remove the previous join before trying this join).
15. **Intersect** the joined layer with the generalized zoning data layer.
16. **Intersect** parcel/zoning intersect result with the landriversegments for the applicable county.
17. **OUTPUT 5** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.
18. *EXCEL:* Import OUTPUT 5 to Excel. Populate an FID for OUTPUT 5 in the same order (ensure no sorting occurred), select the LandRivSeg, LU, GENZONE, and tt_acre fields to add to the 'Res_Dev_YEAR_increase' tab. Note, the names of these LU field is often stripped during intersecting. Using the ratio calculated in Step 11 above (VLOOKUP), estimate the incremental increase in residential impervious surface from the baseline year to 2012 from the baseline impervious surface condition for each parcel (OUTPUT 5 * ratio). Sum by segment in the results tab.

Correction factor for increase in acres already accounted for in baseline impervious data

19. **Intersect** the layer created in step 16 (represents parcel area increase from baseline) with the baseline impervious dataset.[1] Using only FIDs may be helpful to limit processing time. If the impervious data was not dissolved initially an additional step of dissolving this intersected layer may be helpful prior to exporting.
20. **OUTPUT 6** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.
21. *EXCEL:* Enter values in Excel as the correction factor using the FID from OUTPUT 5 to VLOOKUP OUTPUT 6. Some FIDs may be missing from OUTPUT 6 if no impervious surfaces are within a parcel. The SUMIF function may be used if multiple FIDs from OUTPUT 5 are produced.

Non-Residential Development (commercial, industrial) Projection

Same methodology as residential impervious but uses the "CIUSE field", dissolves by "CIUSE" group, and does not use zoning. All processing files organized in a "Nonresidential folder" and numbered "n1, n2, n3".

Non-Residential development through baseline year

1. Add a field to the MDP County Parcel Points file with a numeric ID (e.g., 0-14) called "NonRes_ID" that corresponds to the use group of "CIUSE" using the queries in the Excel table 'Nonresidential_query_crosswalk_appendix E.xlsx'[2]. First set all rows to '9999' and then use the queries to change the entries to the appropriate "NonRes_ID".
2. From MDP County Parcel Points file, select non-residential parcels through the baseline year. **Select by Attributes** using this query:

---

[1] Initial methods applied the correction factor to dissolved parcels instead of individual parcels and upon quality assurance reviews proved to be too coarse of a correction. By applying to individual parcels, a more accurate outcome is obtained.

[2] Developed from Appendix E of http://planning.maryland.gov/pdf/OurProducts/propertyMapProducts/mdpusr.pdf

(("CIUSE" >= '04000' AND "CIUSE" < '08100') OR ("CIUSE" >= '11000' AND "CIUSE" <= '58000') OR ("CIUSE" >= '60700' AND "CIUSE" < '72000') OR ("CIUSE" > '72000' AND "CIUSE" <= '80110')) AND "YEARBLT" <= *'XXXX'* AND "NFMIMPVL" >=10000 AND "LU" <> 'A' AND "LU" <> 'U' AND "LU" <> 'TH' AND "LU" <> 'R'

     i. *Change years in formula to the year prior to the imagery – best estimate of the parcels present when the imagery was taken (e.g., impervious data year 2008, use 2007).*

2. **Export data** to create a new shapefile with these selected records.
3. **Join** new point shapefile to MDP parcel polygons using the "ACCTID" field. Keep only matching records. This will select only those polygons that correspond to the ACCTIDs of the selected points layer.
4. **Dissolve** by the commercial use group field added ("NonRes_ID"). No '9999' values should be included.
5. **OUTPUT 7** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.

Impervious Data and Non-Residential development through baseline year

6. Impervious data – may need to **merge** data depending upon county, **dissolve** if possible, but in some cases too many records are included so an error will result.
7. **Intersect** impervious data layer with parcel_usegroup _dissolve table from step 5 above. Only dissolve by FID of the step 5 table to save processing time and allow the next step of dissolving to function more efficiently. Be careful when only using FIDs to check for missing NonResIDs that would throw the order out of sync.
8. **Dissolve** by the FID of the output table of the previous step (ensure the "NonRes_ID" corresponds to the FID or lookup the values from OUTPUT 7).
9. **OUTPUT 8** - Calculate area for the portion that intersects. Export resulting table as a text file to the output folder.
10. *EXCEL:* Calculate the ratio of the acreage from OUTPUT 7 to OUTPUT 8 – to develop an impervious coefficient per parcel type/CIUSE type.

Non-Residential development since baseline year (bridging gap from impervious data baseline year through 2012)

11. **Select by attributes** single family residential parcels from parcel point data using the following query:

    (("CIUSE" >= '04000' AND "CIUSE" < '08100') OR ("CIUSE" >= '11000' AND "CIUSE" <= '58000') OR ("CIUSE" >= '60700' AND "CIUSE" < '72000') OR ("CIUSE" > '72000' AND "CIUSE" <= '80110')) AND "YEARBLT" > *'XXXX' AND* "YEARBLT" <= *'2012'* AND "NFMIMPVL" >=10000 AND "LU" <> 'A' AND "LU" <> 'U' AND "LU" <> 'TH' AND "LU" <> 'R'

    a. *Change years in formula to the year prior to the imagery. This represent the parcels built since the impervious data layer was developed (e.g., impervious data year = 2008, use 2007).*

12. **Export data** to create a new shapefile with these selected records.

13. **Join** new point shapefile to parcel polygons using the "ACCTID" field. Keep only those that match. This will select only those polygons that correspond to the "ACCTIDs" of the selected points layer (Be sure to remove the previous join before trying this join).

14. **Intersect** parcel/group use join with the landriversegments for the applicable county.

15. **OUTPUT 9** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.

16. *EXCEL:* Using the ratio calculated in Step 10 above, estimate the incremental increase in non-residential impervious surface from the baseline year to 2012 using the baseline impervious surface condition (OUTPUT 9 * ratio). Sum by segment in the results tab.

17. *EXCEL:* Import OUTPUT 9 to Excel. Populate an FID for OUTPUT 9 in the same order (ensure no sorting occurred), select the LandRivSeg, Non_Res_ID, and tt_acre fields to add to the 'NonRes_YEAR_increase' tab. Note, the name of the "NonRes_ID" field is often stripped during intersecting – it is the last numeric 0-14 field prior to the FID of the segment field. Using the ratio calculated in Step 11 above (VLOOKUP), estimate the incremental increase in non-residential impervious surface from the baseline year to 2012 from the baseline impervious surface condition for each parcel (OUTPUT 9 * ratio). Sum by segment in the results tab.

Correction factor for increase in acres already accounted for in baseline impervious data

18. **Intersect** the layer created in step 14 (represents parcel area increase from baseline) with the baseline impervious dataset.[3] Using only FIDs may be helpful to limit processing time. If the impervious data was not dissolved initially an additional step of dissolving this intersected layer may be needed prior to exporting.

19. **OUTPUT 10** - Add new column to resulting table (tt_acre), double. **Calculate geometry** in acres. Export resulting table as a text file to the output folder.

20. *EXCEL:* Enter values in Excel as the correction factor using the FID from OUTPUT 9 to VLOOKUP OUTPUT 10. Some FIDs may be missing from OUTPUT 10 if no impervious surfaces are within a parcel. The SUMIF function may be used if multiple FIDs from OUTPUT 9 are produced.

Road Impervious Calculations

The following methods were used to determine the portion of data that can be attributed to roads. Roads include primary surface roads, not driveways, sidewalks, paths, or parking areas in following CBP definitions. Gravel and dirt roads were considered as impervious. 2013 NAVTEQ roads data were received from CBP in June 2015 as a shapefile buffered to within 1 km of the Maryland border.

NAVTEQ Streets are linear shapefiles which can be buffered using lane width data to provide road impervious estimates such as (1) area of baseline impervious attributable to roads; and (2) area of roads built since the baseline impervious data year (not captured in impervious baseline data – missing or not constructed).

For those counties with a separate designation for roads in the baseline impervious data, planimetric data were used to calculate the impervious road area. For those counties without a separate designation, buffered NAVTEQ linework were used to calculate impervious road area.

---

[3] Initial methods applied the correction factor to dissolve parcels instead of individual parcels and upon quality assurance reviews proved to be too coarse of a correction. By applying to individual parcels, a more accurate outcome is obtained.

Buffered NAVTEQ roads were also used to calculate the area of roads built since the baseline year. Buffered NAVTEQ roads were intersected with the existing baseline impervious surface to ensure the surface was not already captured in the baseline dataset. Based on the portion of area that overlaps, a road was designated as a "new" or "missing" road. County-specific error assessments of how well NAVTEQ lined up with each counties' planimetric data was used to select the appropriate overlap threshold that limited introducing unnecessary error into the planimetric data. See 'new_missing_road_selection_criteria - 8-6-2015.xlsx' for a more detailed description.

NAVTEQ Pre-processing

- Provided as clipped to within 1 km outside of Maryland state border.
- Reproject to same projection as other impervious data.
- Select columns of interest to limit file size.
- Remove non-road features:
    o Lanes within parking lots (Plot_roads=Y)
    o Ferry boat routes (ferry_routes=B)
    o Tunnels (tunnel=Y)
    o Pedestrian walkways (AR_AUTO=N AND AR_PEDEST=Y)
- Final file: 'NAVTEQ_2013_Streets_processing_projected_final.shp'.

Procedure to Buffer Linear NAVTEQ Roads Data

NAVTEQ roads data include several fields that provide information on the number of lanes. A description of these fields is included below from the 2013 NAVSTREETS Street Data Reference Manual:

Field	Name	Description
PHYS_LANES	Physical Number of Lanes	1-32 to indicate physical number of lanes. Only populated for certain roads. Used as the primary field when available.
TO_LANES & FROM_LANES	To Lanes and From Lanes	Together indicate the number of lanes in each direction of travel (1-16). 0 indicates data unavailable. Summed and used as the secondary field when PHYS_LANES not available.
LANE_CAT	Lane Category	Classifies a road based on number of lanes in either direction. Always populated. 1 - One Lane; 2 - Two or Three Lanes; 3 - Four or More Lanes Use as tertiary field when other fields not available. 1= 2 lanes, 2 = 2.5 lanes (between 2 and 3), 3 = 5 lanes.

To buffer NAVTEQ centerline data, in order of preference the 1). "PHYS_LANE" field, 2). "TO_LANES" and "FROM_LANES" fields; and 3). "LANE_CAT" field data were utilized. The "PHYS_LANES" field was used without modification, while "TO_LANES" and "FROM_LANES" fields are summed to arrive at total lanes. "LANE_CAT" can have a value of 1, 2, or 3 and was interpreted as described in the table above.[4]

---

[4] Of 406,904 road segments within 1 km of Maryland, 311,247 have LANE_CAT=1 and other lanes fields=0, 914 road segments have LANE_CAT=2 and other lane fields=0, and 0 road segments have LANE_CAT=3 and other lane fields=0.

Shoulder Width: MD SHA guidelines specify a 5 ft shoulder lane for multiple lane roads (10 ft total). [5] NAVTEQ includes a "DIVIDER" field that indicates whether a road is a divided highway and would tend to have 4 shoulders instead of just 2. This field will be used to either apply a 10 ft additional buffer to multiple lane roads without dividers or a 20 ft additional buffer to multiple lane roads with dividers.

Ultimately, the number of lanes is determind based on the hierarchy of fields discussed above, using a 12 ft average lane width according to MD SHA guidelines, and adding shoulder width for those roads with multiple lanes:

1. #lanes <2 – 12 ft x lanes + no shoulder
2. #lanes>2 and not a divided highway – 12 ft x lanes + 10 ft shoulder
3. #lanes>2 and a divided highway – 12 ft x lanes + 20 ft shoulder

Note that NAVTEQ lines sometimes appear to follow the dividing lane rather than centerline when number of lanes in each direction is not equal – so spatially the width may be slightly offset. Since estimate are tabular, this does not seem to be a major concern. In addition, it is acknowledged that lane width, shoulder width, and median width vary considerably from the design standards and is a limitation of using these data.

The 'NAVSTREETS_GIS.csv' file contain these executed lane width assumptions.

The table below shows the impervious data year and whether roads are specified in the county planimetric data using a separate designation. A slightly different methodology is warranted when roads cannot be readily extracted from the county planimetric data.

County	Imp Data year	Roads specified	Method
Anne Arundel	2011	Yes	Separate designation
Baltimore City	2008	Yes	Separate designation
Calvert	2011	Yes	Separate designation
Caroline	2008	Yes	Separate designation
Charles	2011	Yes	Separate designation
Frederick	2005	Yes	Separate designation
Talbot	2010	Yes	Separate designation
Carroll	2014	Yes	Separate designation – no projection needed
Howard	2013	Yes	Separate designation – no projection needed
Baltimore County	2008	Yes	Separate designation - raster methods
Montgomery	2010	Yes	Separate designation - raster methods (due to data processing issues with vector methods)
Dorchester	2010	No	No separate designation
Harford	2011	No	No separate designation
Prince George's	2009	No	No separate designation
Queen Anne's	2008	No	No separate designation

---

[5] MD SHA Design Manual http://marylandroads.com/Index.aspx?PageId=453

County	Imp Data year	Roads specified	Method
Wicomico	2013 planimetric 2006 roads	Yes	No separate designation – no projection needed for non-roads
Allegany	2005	NA	Missing/unusable planimetric road data
Kent	2004	NA	Missing/unusable planimetric road data
Cecil	2013	NA	Missing/unusable planimetric road data – no projection needed

Counties with a Separate Road Designation in Planimetric Data

Area of baseline impervious roads:

1. Isolate the road portion of the baseline impervious dataset. Document the method used in the Excel readme tab (should include paved/unpaved roads, no sidewalks, driveways, runways, parking lots).
2. **Intersect** impervious roads with landriversegments.
3. **Dissolve** by segment. **Calculate geometry** (acres) of baseline impervious roads. Export results as text file. Add as new column to calculation output Excel sheet.

To account for roads built since the baseline year:

4. **Clip** NAVTEQ lines ('NAVTEQ_2013_Streets_processing_projected_final')[6] by a dissolved County landriversegments layer to select only those roads in the County.
5. **Join** the 'tt_buff_m' field from the 'NAVSTREETS_GIS.csv' file to the line file using the 'OBJECTID field. This csv file is the result of the buffer methodology and provides a field to use to buffer the linework.
6. **Export** the joined linework data as a new shapefile.[7]
7. **Buffer** NAVTEQ lines using the 'tt_buff_m' field. Ensure Side Type remains as 'FULL' and change End Type to 'FLAT' – (ARCINFO license needed). No dissolve.
8. Create a new field called 'tt_sqm_1'. **Calculate geometry** (square meters).
9. **Intersect** with baseline impervious data (use all data not just roads here as we found NAVTEQ and counties vary in the classification of what is a road/driveway/parking area/neighborhood road/path).
10. **Dissolve** by NAVTEQ 'OBJECTID'.
11. Create a new field called 'tt_sqm_2'. Re**calculate geometry** (square meters).
12. **Join** to original buffered NAVTEQ roads shapefile (created in step 7) using the 'OBJECTID' field.
13. **Export data** as a new shapefile.
14. Add a 'tt_per' field. Use the **field calculator** to evaluate the expression '[tt_sqm_2] / [tt_sqm_1]'. This calculates the portion of the area already accounted for in the impervious roads data.

---

[6] These data were processed to select only fields of interest, reproject for comparability, and remove non-road features.
[7] Exporting as a new shapefile can in some instances be time consuming. The 'Copy Features' tool seems to work more consistently in those cases.

15. **Select by attributes** only those with a 'tt_per' < 25%. These represent "new" roads or roads that were not included in the existing impervious data. Note that the final selection percentage used was less than 25% in some cases for counties where NAVTEQ roads did not spatially align as accurately with planimetric data, leading to unacceptable high error rates (see 'new_missing_road_selection_criteria - 8-6-2015.xlsx').
16. **Export data** to a new shapefile.
17. Use **Erase** (ArcInfo) to remove the portion of the baseline impervious data (use all, not just roads) that overlaps with the lt 25% "new" roads (Input lt 25 roads, erase county impervious).
18. **Intersect** leftover new roads with landriversegments.
19. **Dissolve** by segment. Add 'tt_acre' field and **calculate geometry** (acres) of new impervious roads. Export results as text file. Add as new column to calculation output Excel sheet.

To calculate totals:
- ❖ Total impervious surface 2012 = baseline impervious + projected res + projected non-res + incremental new roads identified using NAVTEQ.
- ❖ Road impervious surface 2012 = baseline planimetric road area + NAVTEQ 2012.
- ❖ Non-road impervious surface 2012 = Total impervious surface - Road impervious surface 2012.

Counties with NO Separate Road Designation in Planimetric Data

Same methods as above. <u>One exception</u> - Use NAVTEQ as the 2012 total roads area instead of attempting to isolate the area of impervious roads from the county planimetric data (skip steps 1-3).

To calculate total 2012 road area using NAVTEQ, use the output of step 8 above, Intersect with landriversegments, dissolve by segment, calculate area (acres), and export as text file to an output folder.

NOTE: Still determine the portion of road impervious from the baseline year through 2012 to add to the baseline impervious using the same methods described above (baseline impervious will not include roads from baseline year to 2012, so 2012 roads will not be a subset unless this area of new roads is determined).

To calculate totals:
- ❖ Total impervious surface 2012 = baseline impervious + projected res + projected non-res + incremental new roads identified using NAVTEQ.
- ❖ Road impervious surface 2012 = NAVTEQ 2012.
- ❖ Non-road impervious surface 2012 = Total impervious surface - Road impervious surface 2012.

Counties with 2012 or More Recent Road Impervious Data
(Carroll/Howard)
No projection was needed as the planimetric data were representative of 2012 conditions, therefore only steps 1-3 above were needed using the planimetric data to calculate the road portion of impervious area. Carroll and Howard had a separate road designation.

Counties with Raster Processing Methods
(Montgomery/Baltimore County)

Baseline impervious roads:
For Baltimore County, impervious data were best represented by vector planimetric data **mosaic**ed with impervious land uses in a high resolution land use dataset. To determine baseline year road impervious area, ONLY the planimetric feature types corresponding to roads were used to calculate area by segment. Land use data were not used since the land use of 'transportation surfaces' includes parking areas and other non-road features.

For Montgomery County two planimetric datasets were combined and processed as a raster due to processing times. Attempting to use the vector planimetric data and intersect resulted in repeated errors in ArcGIS. Montgomery County had a separate designation for roads in the original "export_output" dataset using the following two queries "WQPC_DESC" = 'PD' AND "WQPC_TYPE" = 'ROW'. Then add to this "WQPC_STYPE" = 'PR'.) However these data did not include a designation for SHA roads so the county supplied a 2014/2015 dataset to identify and include SHA roads. Roads "WQPC_STYPE" = 'SHA' were selected and clipped out from the 2012 dataset to exclude any roads we don't want to capture that might have been built from 2012-2014. These SHA roads were merged and dissolved with the roads generated from the 2012 road data.

To calculate incremental road increase (same methods for both counties):
Purely using the raster data and tabulating area using buffered NAVTEQ roads also resulted in errors as the buffered NAVTEQ road polygons overlap at the intersections. By using raster data to select new roads and then relinking back to vector data, over-counting was avoided.

1. Convert buffered NAVTEQ roads to raster (**Convert features to raster**) using the 'OBJECTID' as the value, snapped to extent of overall impervious surface raster data "imp_ras" ('mos_ras' for Baltimore County) to create 'nav_ras'.
2. **Build raster attribute table** for 'nav_ras'.
3. Add a field called 'tt_sqm1' and use the **field calculator** to determine area by multiplying the pixel count by cell size (MOCO - 0.91440183m x 0.91440183m = 0.836130707 m2; BCO - 0.60960122m x 0.60960122m = 0.371613647 m2).
4. **Tabulate area** using 'nav_ras' with the 'OBJECTID' (VALUE) as the zones and 'imp_ras' overall impervious surface as the value – this determines the portion of each 'nav_ras' road segment that overlaps with impervious pixels (basically the equivalent of 'tt_sqm_2' in previous methods.
5. **Join** to original 'nav_ras' raster NAVTEQ roads file using the 'OBJECTID' (VALUE) field.
6. **Export data** as a new shapefile (GRID format). This is 'nav_ras1'.
7. **Replace 'tt_sqm_2' values of <Null>** with 0. These are segments without any overlap and should be counted as new roads, but the 'tt_per' column will be null unless the values are changed. Use the OID column to sort by 0, then select the null values and use the field calculator to update.
8. Add a 'tt_per' field. Use the **field calculator** to evaluate the expression '[tt_sqm_2] / [tt_sqm_1]'. This calculates the portion of the area already accounted for in the impervious roads data.
9. Select only those with a 'tt_per' < 25% using **Extract by Attributes**. These represent "new" roads (or roads that were not included in the existing impervious data). See 'new_missing_road_selection_criteria - 8-6-2015.xlsx' for revised selection tolerance for new roads.

10. Re**join** to original vector buffered NAVTEQ data using the 'OBJECTID' in order to report accurately.
11. **Export data** as a new shapefile.
12. **Intersect** leftover new roads with landriversegments.
13. **Dissolve** by segment. Add 'tt_sqm' field and **calculate geometry** (sqm) of new impervious roads.
14. **Tabulate Area** using the dissolved landriversegs (step above) as zones and the raster impervious data as the value to account for the overlap with baseline impervious data.
15. Re**join** the TA result to the dissolve segment file and export as a text file. Subtract the difference between 'tt_sqm' and the TA value for each segment, convert to acres and add to the Excel sheet.

Counties with Missing/Unusable Planimetric Road Data

Some counties were either missing roads entirely (Kent), had unusable roads (Cecil roads include pervious ROW and adjacent sidewalks), or only included large roads but were missing many secondary roads (Allegany).

NAVTEQ road data were used to supplement the impervious dataset using the following methodology. The roads data then were representative of 2012 conditions, so no further projections were needed as they were included in initial impervious surface calculations.

1. **Clip** NAVTEQ lines by a dissolved county landriversegments layer to select only those roads in the county.
2. **Join** the 'tt_buff_m' field from the 'NAVSTREETS_GIS.csv' file to buffer the line file. This follows the buffer methodology to provide a field to use to buffer the linework.
3. **Export** the joined linework data as a new shapefile.
4. **Buffer** NAVTEQ lines using the 'tt_buff_m' field. Ensure Side Type remains as 'FULL' and change End Type to 'FLAT' – (ARCINFO license needed). No dissolve.
5. Create a new field called 'tt_sqm_1'. **Calculate geometry** (square meters).
6. **Intersect** with existing impervious county roads data.
7. **Dissolve** by NAVTEQ 'OBJECTID'.
8. Create a new field called 'tt_sqm_2'. Re**calculate geometry** (square meters).
9. **Join** to original buffered NAVTEQ roads shapefile using the 'OBJECTID' field.
10. **Export data** as a new shapefile.
11. Add a 'tt_per' field. Use the **field calculator** to evaluate the expression '[tt_sqm2] / [tt_sqm_1]'. This calculates the portion of the area already accounted for in the impervious roads data.
12. Select only those with a 'tt_per' < 25% using **Extract by Attributes**. These represent new roads. Export to a new shapefile. See 'new_missing_road_selection_criteria - 8-6-2015.xlsx' for revised selection tolerance for new roads.
13. *Allegany only* **Merge** with existing impervious county roads data and **dissolve**.
14. **Intersect** with landriversegments and calculate **geometry** in acres.
15. *Allegany only* Where NAVTEQ road data overlapped with non-road structures (buildings, driveways, parking lots, runways), the area should be attributed to the county non-road structure, not the road, and should not be double-counted. Road total acreage should be adjusted downward by subtracting the portion of non-road features that overlap with road

structure. (GIS – **merge** non-road GIS features, **intersect** with final road data, **dissolve** by segment, **calculate geometry**, and subtract this values from step 14 values).

Incomplete Planimetric Impervious AND High Resolution Land Use

Baltimore County – Also calculated for Baltimore City and Montgomery County but ultimately this technique was not pursued other than Baltimore County.

These counties are lacking certain features in the planimetric impervious data, but many of these features are included in the impervious portions of the high resolution land use data. This method involves combining the impervious portions of the high resolution land use and the planimetric impervious data in a raster.

1. Ensure all data are in the same projection using the same units – meters.
2. **Extract by attributes** on the high res data to select the impervious surfaces (Buildings, Transportation Surfaces, Other Paved Surfaces attributes - 5,6,7).
3. Convert impervious data to raster (**convert feature to raster**), snap to cells of the high res data from step 1 ('environments' option in the 'polygon to raster' tool), using the same resolution. Set the cell size to the hi res dataset cell size.
4. **Mosaic** the planimetric impervious and impervious land use together as a raster ('mosaic to new raster' tool).
5. **Reclassify** all cell values to '1' (except NoData).
6. Use this layer as the impervious data. Follow the same methods described above, however instead of intersecting and dissolving when using the impervious data, use **Tabulate Area** to sum by zones. Note that this uses the area units of the projection which will be square meters by default, so a conversion to acres will be necessary. Save output files as text files.

Incomplete Planimetric Impervious

Use the same methods as above, but apply correction factors as necessary.

The table below describes coefficients that were applied to account for missing features in the county provided planimetric data. The 'Correction Factors for Missing Features' section below describes the derivation of these coefficients. The 'Residential Coefficient' and 'Non-residential Coefficient' columns indicate the coefficients applied for each county. The 'Overall' column indicates the overall increase in total impervious acres resulting from these missing feature adjustments. Note, Baltimore County was also missing sidewalks, recreational features, driveways < 100 feet, patios, and pools, but these features were accounted for using the combined datasets rather than coefficients.

County	Patios	Patios < 200 sq ft	Pools	Recreational Features	Buildings < 200 sq ft	Secondary Sidewalks	All Sidewalks	All Driveways	Driveways < 100 ft	Parking Areas	Residential Coefficient	Non-residential Coefficient	Overall
Allegany	x		x	x			x				11%	5%	3%

County	Patios	Patios < 200 sq ft	Pools	Recreational Features	Buildings < 200 sq ft	Secondary Sidewalks	All Sidewalks	All Driveways	Driveways < 100 ft	Parking Areas	Residential Coefficient	Non-residential Coefficient	Overall
Baltimore City	x					x					9%	2%	3%
Baltimore County	x		x	x			x		x		NA	NA	NA
Caroline	x		x				x				11%	4%	3%
Carroll	x		x			x					10%	2%	4%
Cecil	x		x	x			x	x		x	49%	66%	31%
Charles		x				x			x		10%	2%	4%
Frederick	x		x	x		x					10%	3%	3%
Howard	x			x	x	x					10%	3%	4%
Kent	x		x	x			x	x		x	49%	66%	21%
Montgomery	I		I			I/O		I			I - 46% O - 2%	I - 5% O - 2%	3%
Queen Anne's	x*					x*		x*			15%*	3%*	3%
Talbot	x			x			x				10%	5%	4%
Wicomico							S/N			N	S - 3% N - 5%	S - 4% N - 62%	9%

*partially captured, does not apply to growth areas

I – Inside municipality

O – Outside municipality

S – Salisbury

N –Not in Salisbury

Correction Factor for Datasets Lacking Secondary Sidewalks

A correction factor of a 2 percent increase in impervious surface was determined to be necessary on residential and commercial parcels as a best estimate to correct for the lack of secondary sidewalks included in several impervious dataset. Secondary sidewalks are those sidewalks that lead form the driveway to front door, or primary sidewalk to front door, or around a house. Several datasets did not capture these sidewalks. A correction factor of 2 percent was determined using Anne Arundel County as a surrogate. For full methods see the 'Secondary Sidewalk Method_4_22_2015.docx' document. The below methods describe how to apply this ratio:

Ratio Application

1. Calculate the residential impervious area by segment and the non-residential impervious area by segment using the baseline impervious data, apply the 2 percent ratio.
    a. Note residential impervious and non-residential impervious are calculated in previous steps in many cases. To apply these coefficients, those shapefiles should be intersected

with the segment shapefiles to return impervious residential and non-residential by segment.

    b. **Intersect** using the "All" option (do not intersect by "FID Only").

    c. **Dissolve** by the "LndRvrSeg" field.

    d. The 2% ratio was calculated as 2% of impervious area for a county that already included the secondary sidewalks, therefore in order to apply reasonably we need to use the following equation:

> Increase = Residential/Nonresidential Impervious (ac) * feature ratio/(100-feature ratio)
>
> Original+Increase=Total corrected impervious
>
> > For example:
> >
> > 100*2/(100-2)=2.041
> >
> > 100+2.041=102.041

2. Add that amount to each segment. This allows for segments with much more residential or non-residential area compared to those with more roads, etc. (formula does this automatically).

3. Also apply the 2% ratio to the projected increase in residential and non-residential area since the baseline year to 2012 (formula does this automatically).

Correction Coefficient for Missing Features

Coefficients were developed for the four counties with planimetric data that split out features by feature type for nine features (secondary sidewalk distinction developed separately). The table below shows data availability and description for these four counties.

Feature	Anne Arundel	Calvert	Charles	Prince George's
Buildings < 200 sq ft	X	X	X*	X
Sidewalks	X	X	*X**	NA
Patio	X (Patios/Decks)	X (Deck/Pad)	*X**	X
Patio < 200 sq ft	X (Patios/Decks)	X (Deck/Pad)	*X**	X
Pool	X	X	*X**	X (above/in ground)
Athletic Courts	X	X	X*	X
Driveways < 100 ft	X	X	NA	NA
Driveways	X	X	NA	NA
Parking Lots	X	X	NA	NA

*After further review, Charles County was found to be missing several features so data from Charles County were not used in the development of coefficients.

The following methods were used to develop these coefficients:

1. **Extract by attribute** from the impervious surface dataset the feature type corresponding to each feature.

    a. **Calculate geometry** for buildings and patios to isolate those features below provided capture thresholds.

    b. For driveways, as a best estimate, the already generated perimeter field was used to determine length. The perimeter value was divided by 2 and the average width of a small driveway (12 feet) was subtracted from that total: (perimeter/2)-12.

2. Use the same residential/non-residential queries described in this document to determine the area of total impervious surfaces within residential parcels and within non-residential parcels for each county.
    a. This was already determined as part of the previous methodology.
3. **Intersect** each impervious surface feature type with the residential parcels to determine the area of that impervious feature in residential parcels. Compute the ratio of residential feature type to overall impervious residential area.
4. Repeat the above step for non-residential parcels.
5. Repeat until ratios are determined for each feature type for residential and non-residential parcels.
6. To apply the missing feature ratios, see the **Ratio Application** section above.

Missing features coefficients derived from these data are summarized in the table below.

Missing Features Coefficient Results

Residential Parcels

County	Total Impervious	Buildings <200 sq ft		Sidewalks		Patios		Patios <200 sq ft		Pools		Athletic Courts		Driveways <100 ft		All Driveways		Parking Areas	
	ac	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%
Anne Arundel	12,067	131	1%	430	4%	1,048	**9%**	110	**1%**	226	2%	15	0%	1,137	9%	3499	29%	209	2%
Calvert	3,814	37	1%	119	3%	267	**7%**	38	**1%**	58	2%	4	0%	210	5%	1635	43%	55	1%
Charles	4,185	49	1%	15	*0.4%*	33	*1%*	*NA*	*NA*	22	1%	13	0%	NA	NA	NA	NA	NA	NA
Prince George's	12,710	180	1%	NA	NA	583	**5%**	84	**1%**	87	1%	21	0%	NA	NA	NA	NA	NA	NA
State Coefficient Avg			**1%**		**3%**		**7%**		**1%**		**1%**		**0.1%**		**7%**		**36%**		**2%**

Non-Residential Parcels

County	Total Impervious	Buildings <200 sq ft		Sidewalks		Patios		Patios <200 sq ft		Pools		Athletic Courts		Driveways <100 ft		All Driveways		Parking Areas	
	ac	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%	ac	%
Anne Arundel	8,731	7	0%	323	4%	35	0%	3	0.0%	3	0%	70	1%	23	0%	296	3%	4606	53%
Calvert	870	1	0%	39	4%	8	1%	1	0.1%	0.4	0%	8	1%	1	0%	17	2%	558	64%
Charles	2,008	2	0%	49	*2%*	5	*0%*	*NA*	*NA*	0.5	*0%*	84	*4%*	NA	NA	NA	NA	NA	NA
Prince George's	7,552	3	0%	NA	NA	10	0%	1	0.0%	1	0%	11	0.1%	NA	NA	NA	NA	NA	NA
State Coefficient Avg			**0.1%**		4%		**0.5%**		**0.0%**		**0.03%**		1%		**0.2%**		3%		58%