Annual Residential Development in the Delaware River Basin, 2013 and 2014

Methodology – Estimating annual residential development area

The objective of this study was to estimate the annual total land area devoted to new residential development within the Delaware River Basin (DRB). Isolating development in the Delaware River Basin is a challenge, since data on residential development are available for political geographic units, which do not follow watershed boundaries. In order to overcome this challenge, we used residential construction data from the smallest geographic units available - in this case, Census County Subdivisions (generally equivalent to municipalities). Figure 1 shows the difference in area for counties (left) and county subdivisions with a portion of their area within the Delaware River basin (boundary shown in dark green).

The general methodology for estimating annual residential development is to compute the product of the number of residential parcels developed and the average area per residential parcel. To estimate the number of parcels affected, we used building permit data available at the Census County Subdivision level. We used parcel data to compute average residential parcel size. In addition, we added adjustments for the portion of permits representing new development (i.e. excluding permits for renovations), and the portion of the Census County Subdivision area within the DRB. Finally, we separated the data into 1-unit parcels (i.e. single family residential), and multi-unit parcels.

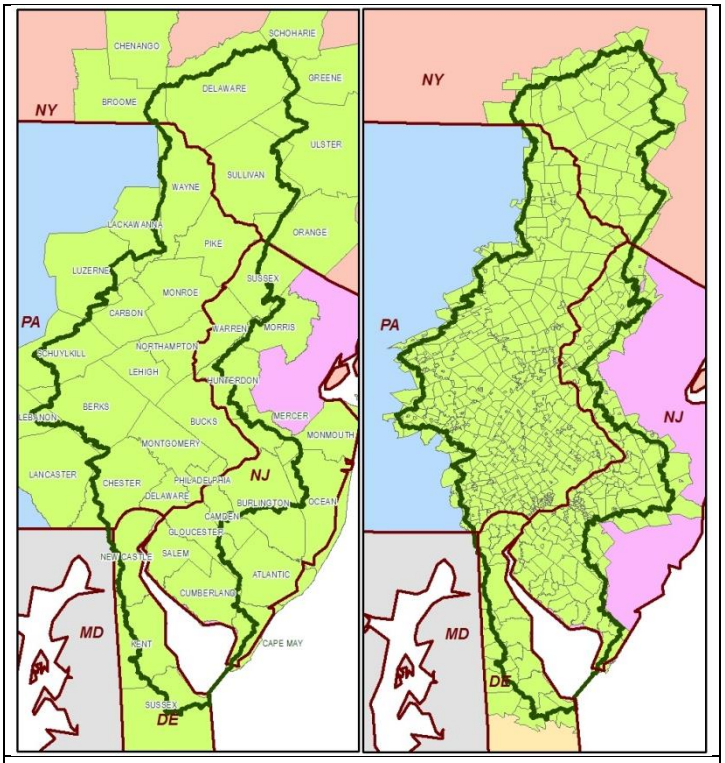

Figure 1. Counties within Delaware River Basin (left) compared to Census County Subdivisions (right) within the DRB.

Equation 1 describes the general methodology for computing the residential development within each County Subdivision (municipality).

$$A_T = BP_{1u} \times a_{1u} \times p_{new,1u} \times R_{DRB} + BP_{mu} \times a_{mu} \times p_{new,mu} \times R_{DRB} \qquad \textit{(Equation 1)}$$

Where: A_T is the total annual development area, $1u$ refers to 1-unit and mu to multi-unit parcels,
BP is the annual number of 1u/mu building permits, a is the per unit area for 1u/mu parcels;
p_{new} is the percentage of building permits for "new" residential development
R_{DRB} is the portion of the county subdivision's area that is within the DRB.

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Building Permits (BP)

This effort aimed to use the best widely available and consistent building permit information for each state in the DRB as the basis for estimating annual residential development area. This project evaluated several possible data sources. US Census Bureau estimates of housing and residential construction are attractive because of their national coverage and availability at sub-county geographic units. We considered both the 2014 American Community Survey (ACS) estimates of housing and the Building Permit Survey (BPS) datasets. For the ACS, computing the number of new households requires taking the difference between two years of data. In this case, for 'data-years' 2014 and 2013 we computed the annual change between 2014 and 2013, and 2013 and 2012, respectively. The ACS "DP04 – Selected Housing Characteristics" table has many different potential data fields tracking the number of households by county subdivisions. We compared three: "VC03 – Total Housing Units", "VC14 – 1-unit detached housing units", and "VC27-Year built: Built 2010 or later". Since the yearly estimates have some uncertainty, computing a yearly change can add to the uncertainty. Furthermore, a yearly difference can result in negative values, something that is certainly possible if housing units are demolished, though more likely a result of uncertainty in the estimates. Table 1 compares the Census Bureau's estimate of the margin of error and percent margin of error, and the percentage of county subdivisions with a negative year-over-year change for the three data fields.

Table 1. Uncertainty in ACS Estimates of Housing Units, and Year-over-year change

	Margin of Error (Res. Units)			Percent Margin of Error (%)			% with negative change		
State/ ACS field:	VC03	VC14	VC27	VC03	VC14	VC27	VC03	VC14	VC27
Delaware	295.9	357.2	91.4	2.7	2.7	0.9	25.0	26.7	0.0
New Jersey	180.5	173.9	27.0	6.4	4.4	2.3	45.1	46.2	5.2
New York	170.3	166.4	23.5	7.5	4.9	1.5	44.2	48.4	6.4
Pennsylvania	143.0	136.3	21.2	8.0	5.4	2.6	46.9	48.3	6.6
Grand Total	***160.5***	***155.6***	***24.6***	***7.3***	***5.0***	***2.3***	***45.4***	***47.1***	***6.1***

We see from the table that the VC27 estimates have the least error (both absolute and percent), and have the lowest percentage of negative year-over-year changes. As a result, we do not recommend using ACS estimates of total housing units (VC03) or 1-unit detached units (VC14) for any purposes that require a year over year difference on a sub-county level.

The Census Bureau has another dataset that does not require computing year-over-year change, and is more targeted specifically at new residential construction: the Census Building Permit Survey. This dataset is available by census place (which generally corresponds with census county subdivisions and municipal boundaries), and is assembled through annual surveys sent to municipalities asking for the number of residential building permits issued. The BPS survey tracks both residential units and actual buildings (or parcels) authorized for 1-unit, 2-unit, 3-4 unit, and 5+ unit buildings. As a result, this should be a more accurate estimate of the total parcels developed. For simplicity, we combined 1- and 2-unit into a single category, and all others into a multi-unit category.

For Delaware and New Jersey, state level datasets provide official estimates of the number of residential building permits. These datasets were used for estimating develop-

ment area in Delaware and New Jersey, but also to evaluate which Census dataset is the better choice for estimating residential development in other states. New Jersey's Department of Community Affairs (NJDCA) conducts an annual survey of building permit information for each municipality in the state. The data are totaled by residential units authorized in 1- and 2-unit permits, and multi-unit permits. The Delaware Office of the State Planning Commission (DE OSPC) makes the location of every residential building permit since 2008 available in a geospatial format with statewide coverage. Figure 2 shows a scatterplot comparison for New Jersey of the ACS (purple) and BPS (green) estimates of building permits for 2013 and 2014, totaled by county, versus the NJ DCA building permit data for those counties. The BPS data demonstrated a slightly better fit. Figure 3 shows scatterplots comparing the BPS estimates by *municipality* with NJ DCA data (left), and DE OSPC data (right). The plots show data and lines-of-best-fit from both 2013 and 2014 in blue and red, respectively.

Figure 2. Comparison of ACS and BPS estimates of NJ building permits by county to NJ DCA data.

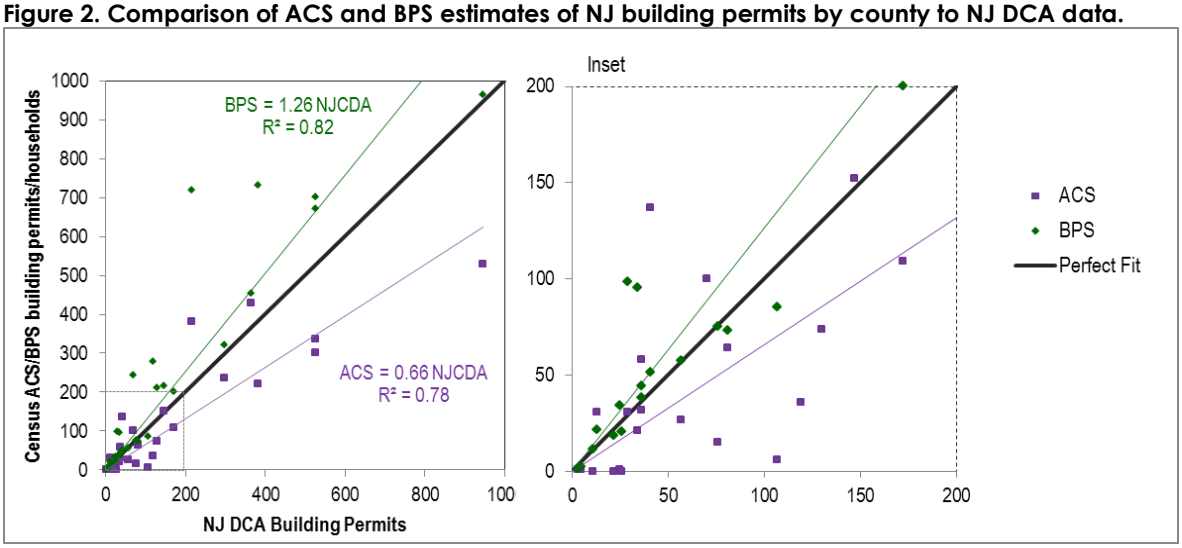
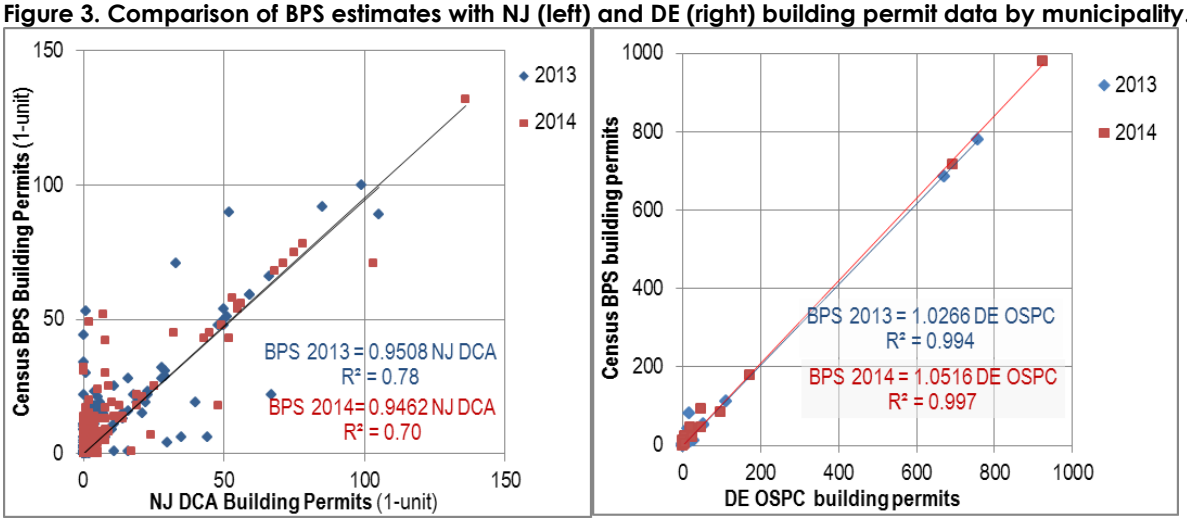


Figure 3. Comparison of BPS estimates with NJ (left) and DE (right) building permit data by municipality.



Based on these comparisons, the Census BPS estimates are selected as the best method for estimating the annual number of residential parcels developed for Pennsylvania and New York. The Delaware data appear to match Census BPS estimates nearly exactly, while the New Jersey data appear subject to more variability. The countywide data in Figure 2 have some discrepancies, which may be in part due to inclusion of both 1-unit and multi-unit buildings. In Figure 3 (at left), only 1-unit permits are considered for municipalities, resulting in a more reasonable slope on the fits (closer to 1), but with similar goodness-of-fit as measured by R^2.

In summary, we selected the following datasets as the most appropriate source for building permits in each state:

- **Delaware** – Delaware Office of State Planning Commission development trends
- **New Jersey** – NJ Department of Community Affairs "Housing units authorized by building permit" data by municipality.
- **New York and Pennsylvania** – US Census Building Permit Survey data by Census place (municipality)

In all cases, we collected data for all geographic units (municipalities or county subdivisions) that are located totally or partially within the DRB. For geographic units partially within the DRB, we adjusted the building permit estimate downward by the ratio of the geographic unit's area within the DRB to the total area of the geographic unit (R_{DRB} in Equation 1). This adjustment is not necessary for Delaware, as all the permits are individually georeferenced.

Area per parcel for new 1-unit development (a_{1u})

To compute residential development area, we multiplied the number of approved permits by average area per new residential unit. In general, we computed average area per 1-unit development based on parcel data available from counties in the DRB area. Depending on attribute data available, we computed these averages for parcels that met the following criteria:

- **Residential**: Have a Land use code/zoning category as 1-unit residential
- **Size**: Less than 5 acres in size[1]
- **Year-Built**: Built after 2010
- **Developed**: Improvement value greater than $10,000 (i.e. a structure is present)

[1] When computing the average parcel size, just a few very large parcels can skew the average. So, since most residential zoned parcels are less than 5 acres in size, and since most very large 1-unit residential parcels are predominantly forested/agricultural, we computed average residential parcel areas *exclusive* of parcels five acres or larger.

We computed the average parcel size within each county subdivision area for parcels meeting these criteria (for as many criteria as could be determined). Data were not available for every county subdivision, so we used nearby county subdivisions or the countywide average to fill in gaps. In cases when fewer than five parcels were available to compute an average, we used the countywide average. Figure 4 shows the average area assumed for new 1-unit residential parcels in this study. As expected, the average parcel size is smaller in more urban areas such as Philadelphia, Camden County, Delaware County, and surrounding areas. The parcel areas tend to be larger in the more rural areas in the upper basin.

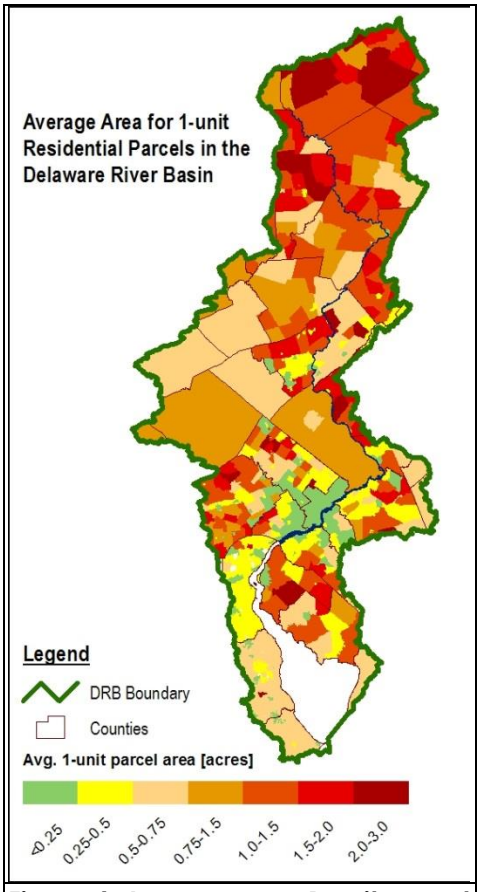


Figure 4. Average new 1-unit parcel area by municipality in the DRB.

Note that in Delaware, the precise parcel developed was known for each building permit, so the averages reflect the actual averages for only these parcels.

Area per parcel for multi-unit developments (a_{mu})

Multi-unit developments come in many different varieties ranging from triplexes and garden apartments to high-rise apartment buildings and large condominium developments. There can be considerable variation in area per parcel depending on the type of development. For the sake of simplicity, we developed some general rules for estimating parcel sizes for multi-unit developments based on some observations from parcel datasets. For parcels coded as condominiums in county parcel datasets (generally in large garden apartment, townhome, or retirement communities), there was a relatively consistent average parcel area of about 0.05 acres. Furthermore, we found that most multi-unit buildings categorized as apartments with multiple residential units were located on parcels between 0.5 and 5 acres. As such, we adopted the following general rules for estimating parcel size based on the number of residential units per building:

- 0 – 10 units: 0.5 acres per parcel
- 10 – 20 units: 2 acres per parcel
- 20 – 50 units: 5 acres per parcel
- Greater than 50 units: 10 acres per parcel

For areas with larger numbers of residential units in multi-unit developments, we used other methods where better data were available. Namely, for Philadelphia County, PA, we used parcel data to compute an average parcel area of 0.25 acres for multi-unit parcels developed after 2010. (High-rise buildings and stacked rowhouses may result in much lower

land area per residential unit than in other portions of the watershed). In Delaware, the building permits were associated with specific parcels, so area could be determined directly.

Portion of Building Permits that are New Development (p_{new})

One final adjustment to the development area estimate was made in order to account for building permits authorizing redevelopment on existing residential parcels. Retrofitting structures on existing residential parcels does not result in significant conversion of other land use types (e.g. forest, vacant, etc.) to residential usage. This analysis attempts to exclude building permits issued for renovations or complete rebuilds of housing on residential parcels. The NJ DCA provides separate building permit data for new construction only. By taking the ratio of the new construction to the total building permits in each municipality, it is possible to determine the percent of all building permits that are part of new developments. We found that the *new* development permits account for 95 percent of total permits on average, with ranges at the county level from about 85 to 100 percent. In most cases, the percentage falls between 94 and 99 percent. Given the relatively small variation across New Jersey, we assumed a default factor of 0.95 (95%) to apply across the watershed, except in Cumberland County, NJ (an outlier at 0.85), and Philadelphia, PA (0.9) due to its density.

Estimating Prior Land Use Breakdowns for Residential Development Area

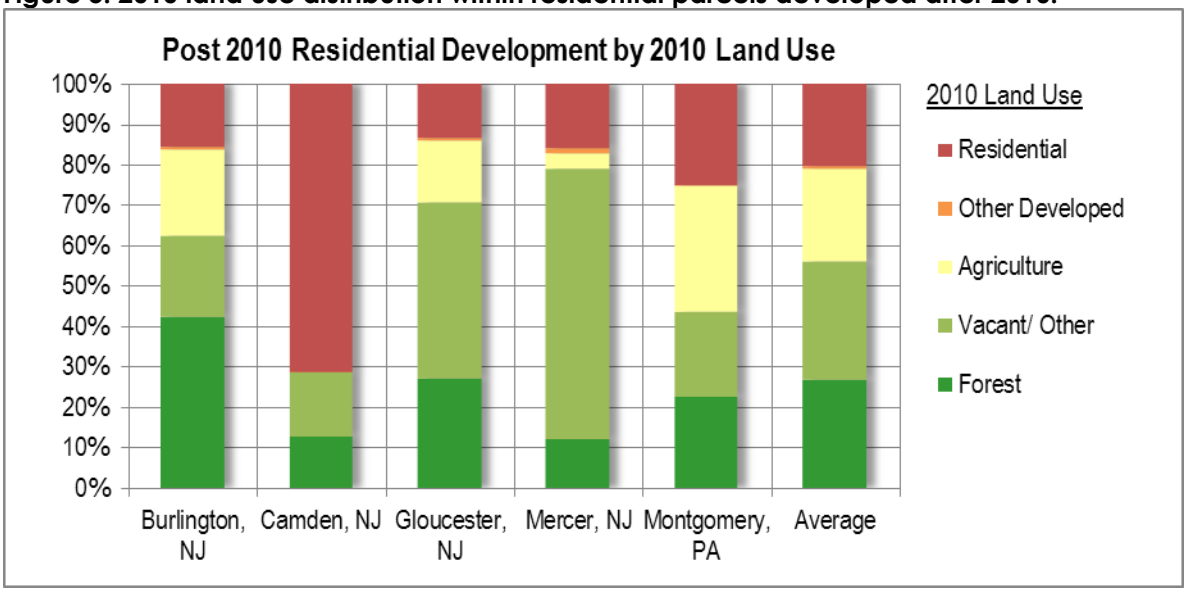
Equation 1 described how to calculate new residential development *area* in the Delaware River Basin. The total area, of course, does not by itself reflect the impact that residential development has on the watershed. Residential development involves a land use conversion from a "prior" land use type to residential use. Estimating the precise land area 'disturbed' for construction of houses and auxiliary structures, driveways and walkways, landscaping, etc., is beyond the scope of this analysis. This analysis does, however, estimate the types of prior land uses converted to new residential usage at the county level.

The approach for estimating the typology of land use change is to compare sequential land use datasets on parcels for which new residential development occurred in the interim. The Delaware Valley Regional Planning Commission (DVRPC) has published detailed land use datasets to detect changes over time in a nine county region encompassing portions of Pennsylvania and New Jersey in the greater Philadelphia area. Specifically, they have published Land Use datasets for 2010 and 2015 digitized at a 1:2400 (1 inch = 200 feet) scale for their nine county area, and made the data available as a GIS feature service. This resolution is sufficient to detect land use changes at the parcel level.

This project used these two land use layers to evaluate the prior land use breakdown of new residential parcels developed after 2010. In five counties (Burlington, Camden, Gloucester, and Mercer, NJ, and Montgomery, PA), the parcel datasets had "Year Built" attributes that allowed isolating the residential parcels with the structure built after 2010. We used standard geospatial analysis tools ("Intersect" in this case) to extract the 2010 DVRPC Land Use data within these parcels. By computing the area for each land use type within these parcels, we determined the area ratios of the prior land use types. We also validated the DVRPC data by repeating the process with the 2015 Land Use data, and found that over 90 percent of the area for these parcels was correctly classified as residential use.

For simplicity, we aggregated the prior land use categories into five main groupings: 1) Forest, 2) Vacant /Other (including open space, grassland, recreation), 3) Agriculture, 4) Other developed (including parking, commercial, transportation, industrial, institutional uses), and 5) Residential. The 2010 land use breakdowns for residential parcels developed in the DRB portions of the five counties from 2011 to 2015 are shown in Figure 5.

Figure 5. 2010 land use distribution within residential parcels developed after 2010.



Sources: DVRPC 2010 Land Use dataset; Parcel data (State of NJ, and Montgomery, PA)

It is clear from the chart that there is considerable variability in prior land uses, even in a relatively small area. Overall, it appears a slight majority of new residential development occurs on land that was previously undeveloped as forest, vacant or other (e.g. grassland, open space, wetlands, barren) land uses. Agricultural to residential land use change accounts for about 20 percent of the land area developed. And on average, another 20 percent of the area has no major land use change, but actually involves redevelopment of existing residential or other developed land. This percentage is considerably larger than the adjustment applied to exclude renovations and rebuilding from the building permit estimates. This large residential portion may reflect larger scale re-developments of neighborhoods, or densification (replacing single family blocks with townhomes or apartments). Alternately, if the neighborhood was built just prior to 2010, the parcels may have been part of a larger residential development, even if the structures were not completed until after 2010.

The results do appear reasonable, though. Camden County (especially the DRB portion) is densely developed, and does not have much vacant or forested area, so it makes sense that the majority of the residential construction occurs on land that is already residential usage (i.e. redevelopment, or infill). Montgomery County traditionally had more agricultural land, so it makes sense that a larger portion of its residential development occurs on agricultural land. Burlington County is more forested, so a larger portion of its new construction occurs on wooded areas.

Extending the Land Use Distribution to the Rest of the DRB

The DVRPC land use data that were available represent a relatively small area of the DRB, but the variations between the counties cover a wide range of development patterns. This project estimated the prior land use distribution for residential development in the DRB by extending the land use distributions in Figure 5 to other counties in the DRB with similar land use characteristics. For each of the other DRB counties, we used overall land use breakdowns and best professional judgment to assign a land use breakdown from one of the five counties or the average. For instance, Philadelphia is most similar to Camden, NJ. Forested areas such as Carbon and Monroe counties are most similar to Burlington County. Bucks and Berks counties both have proportionally more agricultural areas, much like Montgomery County.

Then, based on the percentage breakdown from the relevant county in figure 5, and the total residential development area (in the DRB) for each county, we computed the estimated acreage of forest, vacant/other, agricultural, and residential/other developed land affected by residential development.

Validation of Total Residential Area Developed

The methodology used to estimate annual residential development relied primarily on building permit data and parcel data. There are potential problems with both data sources. The building permits simply report the number of units or building authorized by permit, and not actual development. The Delaware and New Jersey data should reflect exact counts of actual permits that authorized construction, but the Census building permit survey data used for New York and Pennsylvania is based on survey of municipalities, and in some years, data are estimated when the survey is not returned. The average parcel area computed from the parcel datasets may or may not be representative of average new development parcel areas.

We validated our estimates of residential parcel development in Chester County, PA, which has been undergoing rapid development. Under Act 247 of the Pennsylvania Municipalities Planning Code, all subdivision and land development proposals must be submitted to county planning commissions. Many counties produce annual reports describing the annual number of applications received, proposed residential units, and in some cases, area developed. Chester County, PA, goes a step further and has made all land development proposals since 1999 available in a geospatial format on an “arcgisonline” map server (“Plan_Act247_AGOL_D”). The development proposals are available as polygon features and are extensively attributed with fields including the number of residential units proposed, and the year of the proposal.

By intersecting the proposed development area “shapes” with the Chester County parcels (updated in 2016), we were able to determine the actual amount of parcel development that has occurred within the proposed development areas. We computed both the number of parcels developed, and distribution of areas across various parcel land use classifications. Since many of the land development proposals include both residential and non-residential uses, it is important to separate out only residential uses when comparing with the residential development estimates. Chester County has many land use codes that allow further dividing residential land use area into subgroupings. Primarily, we distinguished between

small residential parcels (generally less than 5 acres), apartments, large residential parcels, and vacant residential parcels.

Figure 6 displays the land use distribution within the approved development areas within the DRB portion of Chester County for several years of development. All non-residential land uses are combined into one class, and residential land uses are divided into three categories, plus vacant residential parcels. Since the parcel data reflects 2016 conditions, these vacant parcels indicate house construction has not occurred despite being approved. The land may already have been cleared and prepared for construction in some cases.

Figure 6. Totals by Land Use type in Chester County approved land developments.

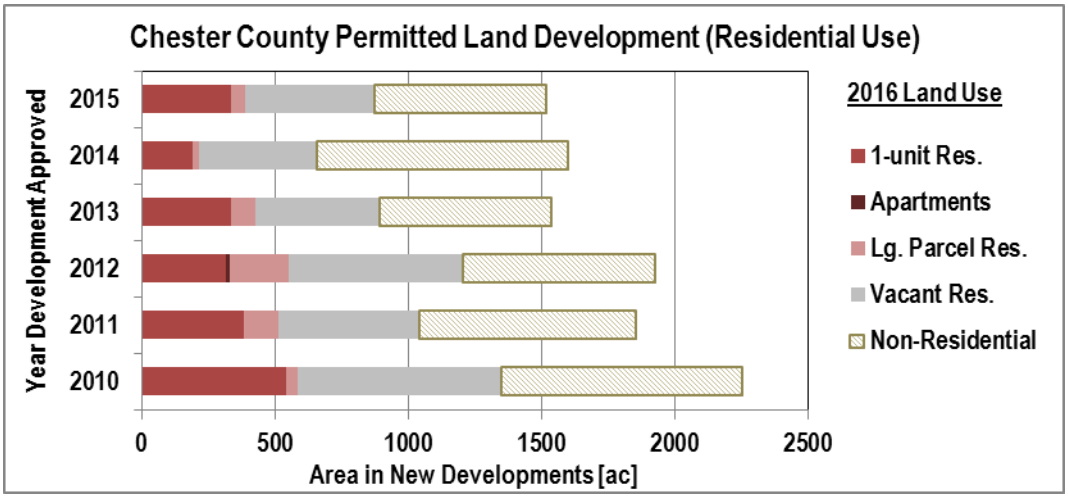


Figure 6 indicates that a relatively large proportion of the land area (30 – 50%) of all developments approved (with residential uses) actually ends up in non-residential parcels. Further, of the area classified as residential, roughly half is found on parcels with land use indicating vacant parcels.

In addition to the total land area, the parcel data allows comparing the number of parcels to estimates of residential units from both the Census BPS and the Chester County approved development data. Table 2 compares these values.

Table 2. Comparisons of residential units, permits, parcels, and area in Chester County

Comparison metric	2013	2014
Residential Units – BPS data	1220	1296
Residential Units – Chester County Approved Developments	490	490
Building Permits – BPS data	1003	773
Actual Residential Parcels developed as of 2016	203	256
Total Area [ac] – BPS method	**816**	**633**
Total Area [ac] – Parcels classified as Residential in 2013, 2014 Chester Co. development (residential + vacant)	**846**	**645**

It is evident from Table 2 that there are significant discrepancies for the number of residential units, and buildings permits/parcels. The BPS data on residential units is roughly 2.5 times larger than the actual units approved in developments. Further, the number of parcels

actually developed lag far behind the assumed number of building permits for development. A possible reason for this is that some parcels may not be subdivided yet, or the development owner may not subdivide the parcel itself despite having multiple units (e.g. for a rental community or retirement community). However, despite these discrepancies, the total residential development areas for the BPS based estimate are very close to the total residential area developed (note: includes the vacant parcels).

Given that the number of residential units/permits in the BPS data was significantly higher than the actual number proposed (and actually developed) in Chester County, the difference must be made up in the average parcel areas. The average parcel area used across Chester County for the BPS based estimation method was 0.86 acres (with a range of 0.09 to 2.4 depending on the municipality). The average actual residential parcel area (non-vacant) within the approved development areas was 1.05 acres. Finally, if all of the residential area (including vacant) in the approved development areas is divided by the number of approved residential units in the approved developments, the resultant average area per unit is 1.58 acres. So indeed, it appears the total areas are a reasonably close match because the actual data have fewer developed units, but on larger average parcel sizes (perhaps due to several large parcels skewing the average).

Finally, we can evaluate the area results on the finer scale of the municipalities. Figure 7 presents a scatter plot of the projected development areas using the BPS estimation method versus the actual development for Chester County municipalities within the DRB.

It is clear from Figure 7 that on the municipal level, there is little correlation between actual development area and the estimated development area. Two main types of errors occur. First, several municipalities have no development area in the estimation because no building permits were recorded in the building permit survey. Second, it appears that many of the municipalities had significantly higher actual development than estimated, likely because the actual developments included a few very large parcels. On the county level, these two errors appear to roughly cancel each other out, leading to a reasonable match for total residential development area in both years.

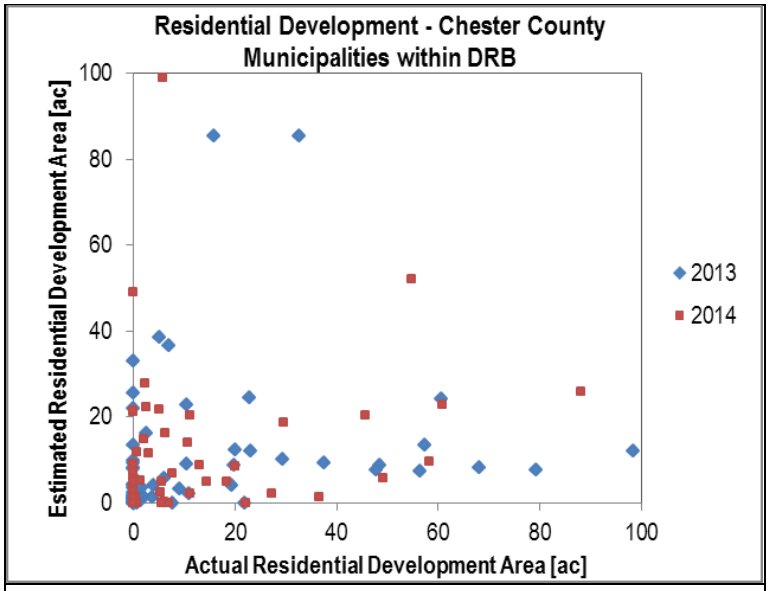


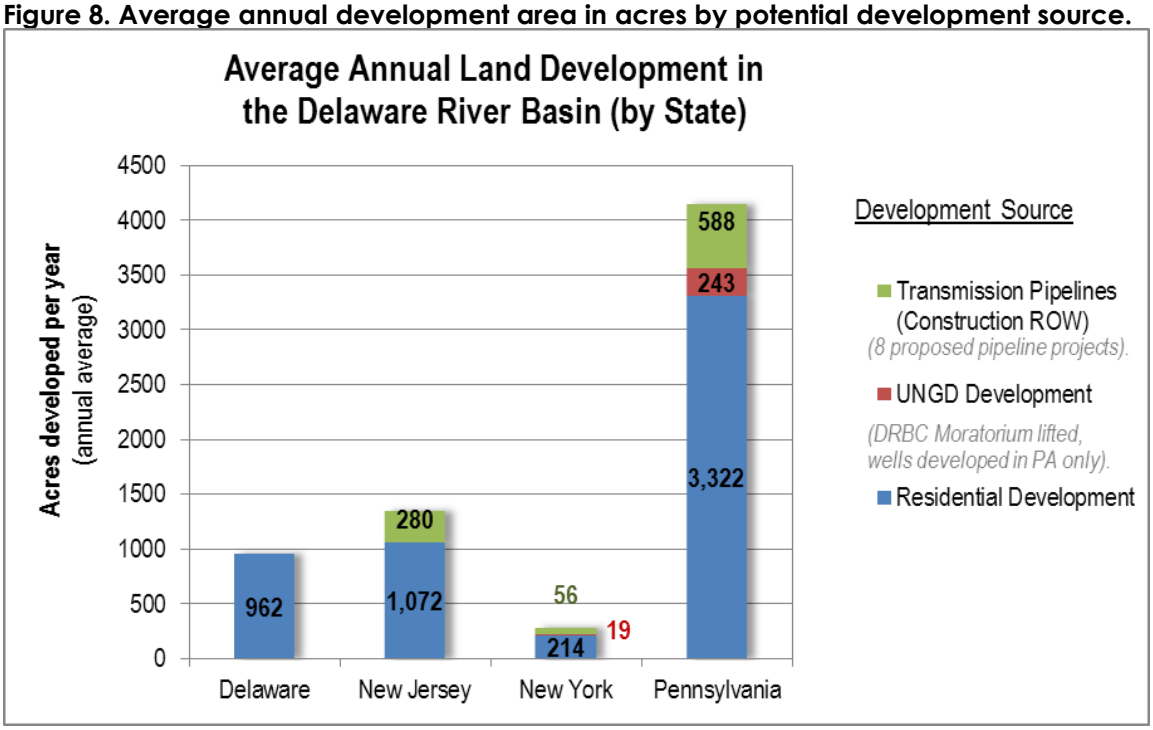
Figure 7. Projected development area versus actual development area by municipality in Chester County, PA.

Results

The results of this analysis are presented in tables, charts, and geospatial format. In addition to the residential development analysis, we have included annual land development estimates for two other types of potential development stressors on the Delaware River Basin. These include potential unconventional natural gas development (UNGD) with hydraulic fracturing, and construction of transmission pipelines to transport natural gas and other hydrocarbon fuels. The potential land use impacts of these development activities were already computed in previous CNA studies, and are presented for context only.

The attached files include results by municipality and county for residential development, and UNGD and pipeline development presented as annual average acreage developed. Figure 8 displays the aggregate results at the state level. In total, the basinwide estimate for annual residential development is 5570 acres per year on average (based on 2013 and 2014). Of that total, roughly 3104 acres is likely new development affecting forests, grasslands, open space and undeveloped area, 1260 acres is converted agricultural land, and about 1206 acres may be redevelopment of existing residential and other developed areas.

Figure 8. Average annual development area in acres by potential development source.



Lessons Learned

In the course of completing these estimates, there were several key takeaways for estimating residential development area.

Use the Best Building Permit Information Available

In Delaware and New Jersey, statewide building permit information is available for each municipality, and gives a more solid basis for estimating development area than Census data. For areas without state or local records, the Census Building Permit Survey data should be used instead of alternate Census housing data such as the American Community Survey (ACS) housing estimates (which require computing year-over-year changes). If the ACS estimates are used, only the more detailed estimates of housing units built in particular years (e.g. after 2010) should be used for year over changes. (Specifically, we suggest field VC27 in table DP04.)

It was beyond of the scope of this study to collect detailed residential construction information from individual counties, but the most complete and accurate estimates of residential construction may be gained in some cases by contacting county planning staffs directly. Furthermore, in Pennsylvania, the Act 247 reporting requirements mean that municipalities generally publish annual reports on the number of building permits approved in each year. These Act 247 annual reports may be a useful source of information for future studies on this topic.

Delaware's building permit information is particularly useful for watershed scale analyses because it is georeferenced to the specific parcels affected. This is helpful because it is easy to determine what portion of the development falls inside versus outside a watershed boundary. In addition, the ability to link the permit to parcel information allows direct computation of development area instead of estimating based on average new parcel size. More states and counties (e.g. Chester County) moving to geospatial permit databases would improve these types of analyses, and make them more efficient in the future.

Detailed Land Use Data Collected at Regular Intervals is very useful

Without the high-resolution land use data provided by the Delaware Valley Regional Planning Commission, estimation of the distribution of prior land uses in residential development areas would have been very difficult. Most land use data available from federal sources is far too coarse (e.g. 30m x 30m) in resolution to be useful in detecting changes at the parcel scale. Collecting more high-resolution land use data at regular (e.g. five-year) intervals for a larger portion of the Delaware River basin would be the best way to track land use changes, and enables much more detailed analysis.

Geographic units - County versus Municipality – Inputs and Outputs

Political boundaries do not often align with watershed boundaries. We found using smaller geographic units is very useful for inputs, but less so for outputs.

Using smaller geographic units allows a much closer alignment with the watershed boundary, and should be subject to less estimation uncertainty. (See Figure 1.) Building permit information is generally available at the municipality (or census county subdivision)

level, so municipalities are an appropriate geographic unit. Since parcel information can be aggregated at any level, the finer geographic units may allow better computation of average parcel size for new development based on local conditions. For example, small cities may add many new residential units, but with a very small average parcel size, while more rural areas may affect a similar land area with only few new units built on large parcels. In general, the finer spatial granularity should improve estimates of residential development made using building permits and average parcel sizes.

The drawback is that the estimates of total area are subject to relatively high error at the municipality level when compared to actual data. Since annual development in municipality may affect only a handful parcels, it is possible the estimates could have significant error especially when the actual development occurs on much larger or smaller parcels than the average size assumed in the estimate. Or, the building permit information could simply be wrong. Our validation for Chester County also found that while the countywide development area results were reasonable, the municipality level results had much more uncertainty. As a result, in areas where development area is estimated based on permits and average parcel area, it is best to present results at a county level. When there is more confidence in the building permit information (e.g. in Delaware), the municipality level results can provide much more information with reasonable confidence.

So, in summary, the estimation of development area should use data from the finest geographic units available, but results should be presented at a geographic scale appropriate to the level of confidence of the data inputs.

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