Memorandum on Land Use Scenario Methodology and Results (Quantitative ICE Assessment Memo #2)

For

Complete 540 – Triangle Expressway Southeast Extension

Wake and Johnston Counties, North Carolina

STIP Nos. R-2721, R-2828, R-2829

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1. Introduction

The North Carolina Department of Transportation (NCDOT) and the Federal Highway Administration (FHWA) propose to build a new, limited-access highway from NC 55 Bypass in Apex to US 64/US 264 Bypass (I-495) in Knightdale, a distance of approximately 28 miles. The project, known as Complete 540-Triangle Expressway Southeast Extension, is proposed as a toll facility.

As part of the National Environmental Policy Act (NEPA) process, NCDOT previously completed a Qualitative Indirect and Cumulative Effects (ICE) Report (December 2014), and a summary of the results is included in the Draft Environmental Impact Statement (DEIS), which was published in November 2015.

As documented in Quantitative ICE Assessment Memo #1, NCDOT and FHWA have determined that using the CommunityViz model from the Imagine 2040: Triangle Regional Land Use Planning Initiative is a reasonable and appropriate tool to develop consistent land use scenario(s) for use in the Quantitative ICE assessment. This approach was chosen because the regional Council of Governments (COG) and the two regional Metropolitan Planning Organizations (MPOs) had utilized this regional scenario planning tool, and the Complete 540 Quantitative ICE assessment is effectively a scenario planning exercise applied to the context of this transportation project. Therefore, the CommunityViz model from the Imagine 2040 initiative provided an existing framework in which to test forecasted land use differences with and without the project.

Since the CommunityViz model has already been calibrated to regional conditions and applied to regionally approved transportation plans, it is logical to use this tool for a Quantitative ICE to forecast future land use in the study area. In ICE Memo #1, the various inputs to the CommunityViz model were reviewed, and the necessary adjustments to those inputs to develop a No-Build scenario were discussed. The adjustments made to the CommunityViz inputs for the 2040 No-Build scenario included the following:

- Reductions to county-level control totals for Wake and Johnston counties,
- Adjustments to Land Suitability Analysis factors associated with Complete 540, and
- Adjustments to the place-type inputs for parcels in the Future Land Use Study Area (FLUSA).

As described in ICE Memo #1, the original Imagine 2040 CommunityViz model land use forecast was determined to represent the 2040 Build scenario, and the CommunityViz model was reused for this effort to produce a 2040 No-Build scenario for future land use without the influence of the Complete 540 project. The model's future land use forecasts were used, as described in this memo, to produce the 2040 No-Build scenario and 2040 Build scenario:

- Land cover for use in analyzing Indirect and Cumulative Impacts (ICI) to Water Quality, and
- Traffic Analysis Zone- (TAZ-) level socioeconomic data.

1.1 Purpose

The purpose of this memorandum (ICE Memo #2) is to follow up on approaches summarized in ICE Memo #1 (see 3 bullet points above) and describe how those outputs were used to forecast land use and land cover changes between base year (Baseline) and 2040 Build and No-Build scenarios. This memo calculates the potential changes in the FLUSA (see Figure 1) using the data from the CommunityViz analyses. These data in turn will be used in the next step to estimate water quality impacts, which will be reported in a forthcoming ICE Memo #3. These data will also be used in a traffic analysis of the 2040 No-Build scenario. The outputs of the forecasting and modeling documented in this memo will be used, along with the Memo #3 and traffic assessment results, to describe the Quantitative ICE process for the proposed facility and summarize results in ICE Memo #4.

This memo (ICE Memo #2) outlines:

1. The methodology used to convert data outputs from the CommunityViz model into land cover results that inform an ICE analysis and can be used by water quality modeling software.
2. A summary of the land cover results from the three scenarios: Baseline, 2040 No-Build, and 2040 Build.
3. A summary of impervious surface percentages by watershed derived from the land cover results.
4. A summary of the TAZ-level household and employment differences in the FLUSA for the No-Build and Build scenarios, based on the CommunityViz forecasts.

1.2 General Approach

Overall, the approach described in this memo is to combine the data outputs of developed land area from the Imagine 2040 initiative with data from the National Land Cover Database (NLCD) on natural land cover areas. The NLCD "serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation" (USGS, 2012). This process was chosen as it would combine information on actual developed land uses from the parcel-level data used in the CommunityViz modeling with data on existing natural land cover for undeveloped areas in the NLCD.

The NLCD is a 30x30-meter resolution raster image of land cover for the entire nation. A raster is a rectangular grid where each cell or pixel within the grid represents one unit of area and contains a value that represents land use or land cover in this analysis. All rasters, in this analysis, were formatted with a 30x30-meter cell size, about one quarter of an acre, to match the NLCD land cover dataset.

This memo describes the land cover results of the land use analysis in the FLUSA for the base year and 2040 with and without the project. Land cover results are tabulated from the final land cover raster files developed using the combination of data from the CommunityViz model and NLCD raster datasets. This memo also provides the TAZ-level socioeconomic data forecast results of the CommunityViz model for the region for the 2040 No-Build scenario.

Figure 1: Project Location and FLUSA Map

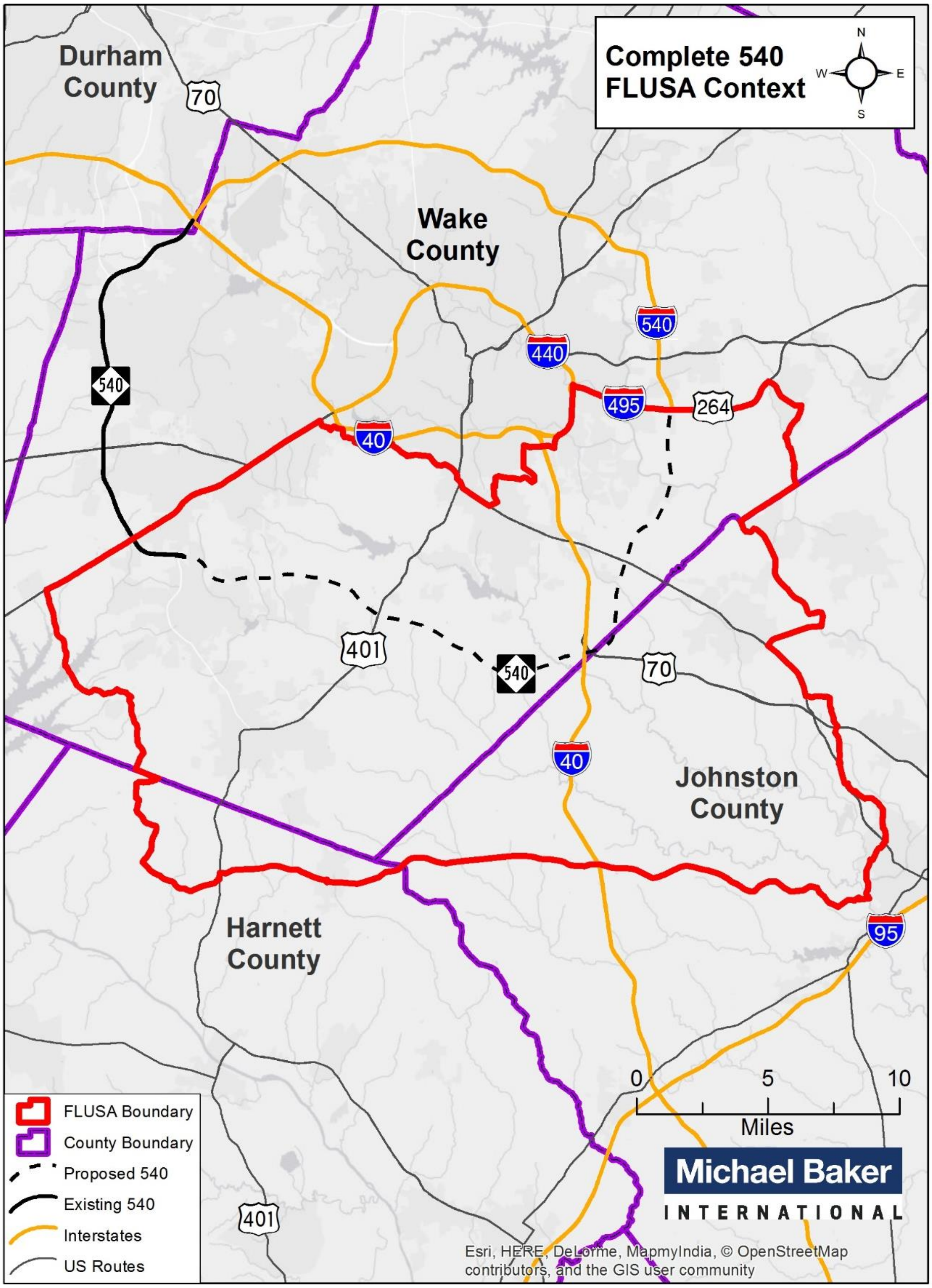
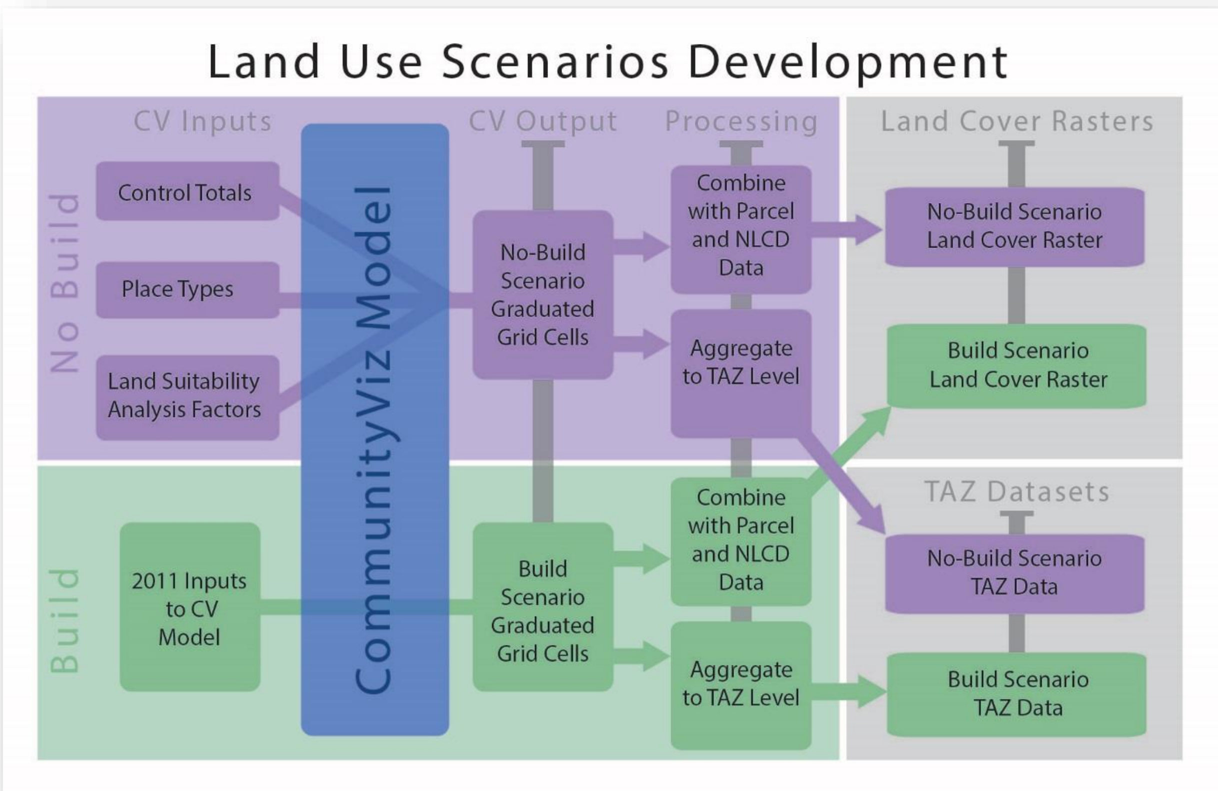


Figure 2 shows the general approach used in the development of the 2040 No-Build scenario and 2040 Build scenario land use forecasts for the ICE analysis. The bottom half of the flow chart shows how the 2011 inputs to the CommunityViz model, as it was run for the Preferred Growth Scenario, resulted in the Build scenario's Graduated Grid Cell Output from CommunityViz. The Graduated Grid Cell output was then aggregated to the TAZ level to create the inputs for the 2040 Build scenario analysis using the regional travel demand model, named the Triangle Regional Model (TRM). The same Graduated Grid Cell output was combined with the parcel and NLCD data to create the 2040 Build scenario Land Cover Raster.

The top half of the flow chart shows the similar process used for the 2040 No-Build scenario. In this instance, however, the three key inputs (i.e., control totals, place types, and land suitability analysis factors) were adjusted before running the CommunityViz model. ICE Memo #1 describes in detail the inputs to the CommunityViz model and the corresponding adjustments made to create the 2040 No-Build scenario. The remainder of this memo more fully describes how the CommunityViz model outputs are used and the resulting land cover data.

Figure 2: Flowchart of Land Use Scenario Development



2. Baseline Land Use Method

To create a basis for comparison of the two future year scenarios (2040 No-Build and 2040 Build), a base year (Baseline) land use scenario was developed using the output data from the CommunityViz model at the parcel level and the NLCD raster layer. To develop the Baseline Land Use Raster, the following key steps were taken:

1. Parcels were differentiated by Existing Development Status (**Developed** or **Not Developed**).
2. **Developed** parcels were coded with an existing land use based on their existing Place Type designation in the Imagine 2040 dataset.
3. Parcels coded as **Not Developed** were assigned an existing land use based on the majority of the land cover within that parcel from the NLCD.

As described in the Imagine 2040 documentation:

> *Development status was assigned to parcels in the region using 2010 aerial photography, property appraiser data, and topic-specific GIS data sets (e.g., existing land use, farmland or vacant land inventories)...Development status categories used for Imagine 2040 include: permanent open space, developed, undeveloped, under-developed, agriculture, and water.*

The Imagine 2040 dataset was generated using the CommunityViz model, which required customized density and intensity control inputs to estimate the development potential for a particular area. A key input to that process is the Place Type. Place Types generalize "the various development categories from zoning and land use plans used by local governments to describe, measure, and evaluate the built environment." (TJCOG, 2013).

Imagine 2040 used 29 Place Types to describe existing and envisioned future land uses within the region. These Place Types were more detailed than typically used in water quality modeling or indirect and cumulative analyses of land use changes. Therefore, the study team converted each Place Type designation into one of seven NLCD Land Use Categories for use in the water quality modeling and ICE land use assessment. Table 1 summarizes the conversion from CommunityViz Place Type to NLCD Land Use Category for all Place Types. For Parks and Open Space, the underlying NLCD inputs were used to determine the appropriate Land Use Category.

The Place Type to NLCD Land Use Category conversion was determined by reviewing the Place Type descriptions from the Imagine 2040 documentation (TJCOG, 2011; 2013) and comparing the typical characteristics of each Place Type compared to the characteristics of the Land Use Categories descriptions from NLCD. The land use and water quality modeling staff used their best judgment to categorize each Place Type into the Land Use Categories. *To provide distinction between the CommunityViz land use information and the NLCD-based information on land cover, the NLCD classifications and data will be referred to as land cover hereafter.*

Table 1: Place Type to Land Cover Category Conversion

Place Type	Place Type Code	Land Cover Code	Land Cover Category[1]
Working Farm	WF	5	Cropland
Light Industrial Center	LIC	2	Low Density Mixed Urban
Health Care Campus	HCC	2	Low Density Mixed Urban
University Campus	UC	2	Low Density Mixed Urban
Mixed-Use Neighborhood	MUN	20	Medium Density Mixed Urban
Village Center	VC	20	Medium Density Mixed Urban
Town Center	TC	20	Medium Density Mixed Urban
Civic & Institutional Facilities	CIV	20	Medium Density Mixed Urban
Neighborhood Commercial Center	NCC	20	Medium Density Mixed Urban
Urban Neighborhood	UN	3	High Density Mixed Urban
Suburban Commercial Center	SCC	3	High Density Mixed Urban
Suburban Hotel	SH	3	High Density Mixed Urban
Suburban Office Center	SOC	3	High Density Mixed Urban
Regional Employment Center	REC	3	High Density Mixed Urban
Heavy Industrial Center	HIC	3	High Density Mixed Urban
Transit-Oriented Development	TOD	3	High Density Mixed Urban
Metropolitan Center	MC	3	High Density Mixed Urban
Mixed-Use Center	MUC	3	High Density Mixed Urban
Airport	AIR	3	High Density Mixed Urban
Rural Living	RL	17	Low Density Residential
Large-Lot Residential Neighborhood	LLRN	17	Low Density Residential
Mobile Home Community	MHC	17	Low Density Residential
Rural Cross Roads	RCR	17	Low Density Residential
Small-Lot, Residential Neighborhood	SLRN	18	Medium Density Residential
Shade Tree Residential Neighborhood	STRN	18	Medium Density Residential
Mixed Residential Neighborhood	MXR	18	Medium Density Residential
Multifamily Residential Neighborhood	MFRN	19	High Density Residential
High-Rise Residential	HRR	19	High Density Residential
Parks and Open Space	POS	Varies[2]	Varies[2]

[1] Density designations in the Land Use Categories are based on NLCD land use classification descriptions.
[2] Underlying NLCD inputs were used to determine the Land Use Category.

For undeveloped parcels, the NLCD raster was used to identify the primary land cover within the parcel. For example, if the majority of the NLCD raster cells within an undeveloped parcel was classified as Cropland, then the Cropland Land Cover Category was applied to the entire parcel. Once all parcels were categorized, the parcel data was converted into a 30x30-meter raster image. Empty areas not covered by parcels were given a Land Cover Category from the NLCD to create a comprehensive Baseline Land Cover Raster to input into the water quality model and for use in comparing land cover results among the three scenarios. The Baseline Land Cover Raster and all other land cover rasters produced for this memo consist of up to 16 Land Cover Categories, summarized in Table 2.

Table 2: NLCD Land Cover Codes and Land Cover Category Descriptions

Land Cover Code	Land Cover Category	Description
1	Water	Lakes, ponds, large streams
2	Low Density Mixed Urban	Mixture of constructed materials, with vegetation mostly in the form of lawn. Schools, hospitals, commercial areas, and industrial parks with extensive, surrounding open land.
3	High Density Mixed Urban	Mixture of constructed materials, with vegetation mostly in the form of lawn. High intensity commercial/industrial/institutional zones.
4	Hay/Pasture	Hay or Pasture
5	Cropland	Row Crops
7	Forest	Coniferous, deciduous, or mixed woodlands
10	Wetland	Woody and emergent wetlands
12	Disturbed	Coal mines, quarries, gravel pits, transitional land
14	Sandy Areas	Beaches and deserts
16	Turf/Golf	Golf courses and sod farms
17	Low Density Residential	Mixture of constructed materials, with vegetation mostly in the form of lawn. Mostly single family housing.
18	Medium Density Residential	Mixture of constructed materials, with vegetation mostly in the form of lawn. Low and medium density housing.
19	High Density Residential	Mixture of constructed materials, with vegetation mostly in the form of lawn. Small lot houses or row houses.
20	Medium Density Mixed Urban	Mixture of constructed materials, with vegetation mostly in the form of lawn. Smaller cities and suburban locations.
21	Open land	Open range/grassland - natural areas
22	Bare Rock	Non-vegetated rocky areas

3. Future No-Build and Build Land Use and Land Cover Method

As described in Quantitative ICE Assessment Memo #1, the basis for the 2040 No-Build scenario and 2040 Build scenario land use datasets is the forecast of dwelling units and employment in the FLUSA, produced through the CommunityViz model used in the Imagine 2040 initiative. Based on coordination with area planners, NCDOT, and FHWA, the original outputs of the Preferred Growth Scenario in Imagine 2040 were concluded to be the 2040 Build scenario for this Quantitative ICE. As described in Quantitative ICE

Assessment Memo #1, a set of revised inputs for control totals, Land Suitability Analysis factors, and Place Types were used to produce a 2040 No-Build scenario land use forecast. For both the 2040 Build and 2040 No-Build scenarios, two key outputs of the CommunityViz model are (or will be) used to assess indirect and cumulative effects:

1. The Graduated Grid Cell output in shapefile (.shp) format, and
2. The TAZ-data output in Data Base File (.dbf) format.

The (Imagine 2040) CommunityViz model uses a Graduated Grid Cell system as a common geography to aggregate parcel-level data and combine it with the Land Suitability Analysis factors in a manageable way for such a large study area (TJCOG, 2013). A key output of the CommunityViz model is the Graduated Grid Cell shapefile attributed with data on the capacity of each grid cell and the allocated growth for each grid cell. This grid cell output formed the basis of the 2040 No-Build scenario and 2040 Build scenario land cover rasters.

To create land cover rasters for both the 2040 No-Build and 2040 Build scenarios, the following general steps were taken to convert the information in the CommunityViz grid cell data into land cover raster data:

1. Within the Graduated Grid Cell shapefile, the number of jobs and dwelling units allocated to each grid cell was divided by the total capacity for that grid cell to determine the percent of capacity used.
2. The grid cell shapefile for each scenario was intersected with undeveloped parcels from the parcel data for each scenario in GIS.
3. From this intersected output, each undeveloped parcel was put into one of three groups:
    a. Group A - Parcels where 75 percent or more of the capacity was used. These parcels were considered fully developed and were categorized as developed in the future land cover rasters.
    b. Group B - Parcels where >0 to 75 percent of the capacity was used. These parcels were further processed through GIS and were reduced in area by the percent of capacity used. The resulting reduced-area parcels were then categorized as developed for use in the future land cover rasters.
    c. Group C - Parcels where 0 percent of the capacity was used were considered undeveloped and were not carried forward for updating the future land cover rasters.
4. Using the future Place Type attributes from the Imagine 2040 initiative for the 2040 Build scenario and the revised future Place Types described in Quantitative ICE Assessment Memo #1 for the 2040 No-Build scenario, each parcel in Groups A and B was attributed with the appropriate Land Cover Category per the lookup table (Table 1). The results of this were two polygon GIS layers:
    a. 2040 No-Build Parcels: currently undeveloped parcels, coded with the Land Cover Category that would be expected to develop by 2040 under the No-Build scenario.
    b. 2040 Build Parcels: currently undeveloped parcels, coded with the expected Land Cover Category that would be expected to develop by 2040 in the Build scenario.
5. Each of these resulting polygon layers was then overlaid on the Baseline Land Cover Raster in GIS to create two new rasters, one each for the 2040 No-Build and 2040 Build scenarios.

For Step 1, the ratio of allocated growth to the total capacity was calculated for each cell within the 2040 No-Build and 2040 Build outputs from CommunityViz. The capacity of each cell was calculated within the CommunityViz model based on the Place Type designation and development status of each parcel within that cell area. For example, if all parcels within a 10-acre cell were designated as undeveloped and were categorized with the Large Lot Residential Neighborhood (LLRN) Place Type in the 2040 No-Build scenario, then the likely capacity of that cell would be about 22 dwelling units, accounting for the densities allowed in the LLRN (3.5 units per acre) and the typical site efficiency factor of 62 percent (meaning that any given site will only be able to use 62 percent of the total area). If the CommunityViz model allocated 22 dwelling units to that grid cell, then the percent of capacity used would be 100 percent.

When the example grid cell was integrated back into the underlying parcel data categorized as Place Type LLRN, it would be placed in Group A because 100 percent of the capacity was used and coded as Land Cover Category 17 (Low Density Residential) per Table 1. This parcel polygon, along with all the others from the 2040 No-Build parcels, would then be added to the Baseline Land Cover Raster to create a 2040 No-Build scenario Land Cover Raster.

For parcels where the percent of capacity used was between 0 and 75 percent, an algorithm in GIS reduced the parcel size to equal the percent of capacity used. If CommunityViz outputs indicated that a specific parcel was expected to fill 50 percent of its capacity, the GIS algorithm would shrink that parcel to half of its original size. While this introduces some randomness to the future land use forecast, it is also a consistent randomness across the FLUSA and is allocated by the model without external bias. The function of this step is to approximate the 'footprint' of development for land cover analysis.

The alternative approach would be for an individual to review each of the more than 35,000 parcels separately to decide which part of each parcel would develop and to manually erase the section that would not develop. This would be an extremely time-intensive exercise and would not meaningfully increase the accuracy of the resulting forecast. It would also likely introduce a reviewer bias to the process.

Table 3 shows the breakdown of the total area of parcels affected by the different approaches to grouping and categorizing parcels for the forecasting process. This example is for the 2040 No-Build scenario, but the results for the 2040 Build scenario are very similar. Approximately 58 percent of the FLUSA area could accept new development based on the development status of parcels in the CommunityViz input data. Of those, the CommunityViz outputs indicated that about 33 percent of the developable area would be fully developed by 2040 and placed in Group A. Parcels comprising another 5 percent of the developable area were determined to be between 75 and 100 percent developed and were also included in Group A. Group A parcels were categorized as fully developed in this analysis. Parcels comprising about 50 percent of the developable area were determined to be between 0 and 75 percent developed (Group B). The GIS algorithm reduced size of Group B parcels to approximate the 'footprint' of development. The remaining parcels making up about 10 percent of the developable area were determined to have zero used capacity based on the CommunityViz results and were considered undeveloped in this analysis (Group C).

Table 3: Example of Parcel Development Forecast Grouping for the 2040 No-Build Scenario

Area	**Acres**	**Percent of Total Parcel**
Total Acres of Parcels in FLUSA[1]	278,660	100%
Acreage of Developable Parcels (coded as undeveloped in CommunityViz)	162,770	58.4% of total area of all parcels
Parcel Group per CommunityViz Results	**Acres**	**Percent of Acreage of Developable Parcels[2]**
Group A: Parcel Acreage with 100% of Capacity Used	52,830	32.5%
Group A: Parcel Acreage with 75%-99% of Capacity Used	7,550	4.6%
Group B: Parcel Acreage between 0% and 75% of Capacity Used	86,430	52.5%
Group C: Parcel Acreage with 0% Capacity Used	15,960	9.8%

[1] The total area of parcels in the FLUSA in this analysis is larger than the total area of the FLUSA due to the overlap of cells and parcels that extend beyond the FLUSA boundary but were included in the effort to categorize and forecast land use.
[2] Sum of the parts does not equal the total due to rounding of each group.

For the 2040 Build scenario, one final adjustment was made to the land cover raster to incorporate the footprint of the proposed Complete 540 highway. In GIS, a buffer polygon was calculated from the centerline of the proposed highway and its associated ramps. For the proposed highway centerline, a buffer of 240 feet total width was used. For each ramp, a buffer of 20 feet was used. These polygons were then aggregated and were attributed with the Low Density Mixed Urban land cover category. This category was chosen as it was consistent with the land cover coding within the NLCD of other major expressways in the region, such as Interstate 40.

4. Land Cover Results

The following sections describe the land cover results for each of the three scenarios, based on the conversion of land use data to land cover data.

4.1 Baseline Scenario

Table 4 shows the land cover results for the Baseline. This reflects the land cover in the FLUSA for 2010-2011, given that the inputs to the Imagine 2040 initiative and the NLCD datasets are from that time period. Figure 3 shows the land cover of the Baseline scenario within the FLUSA.

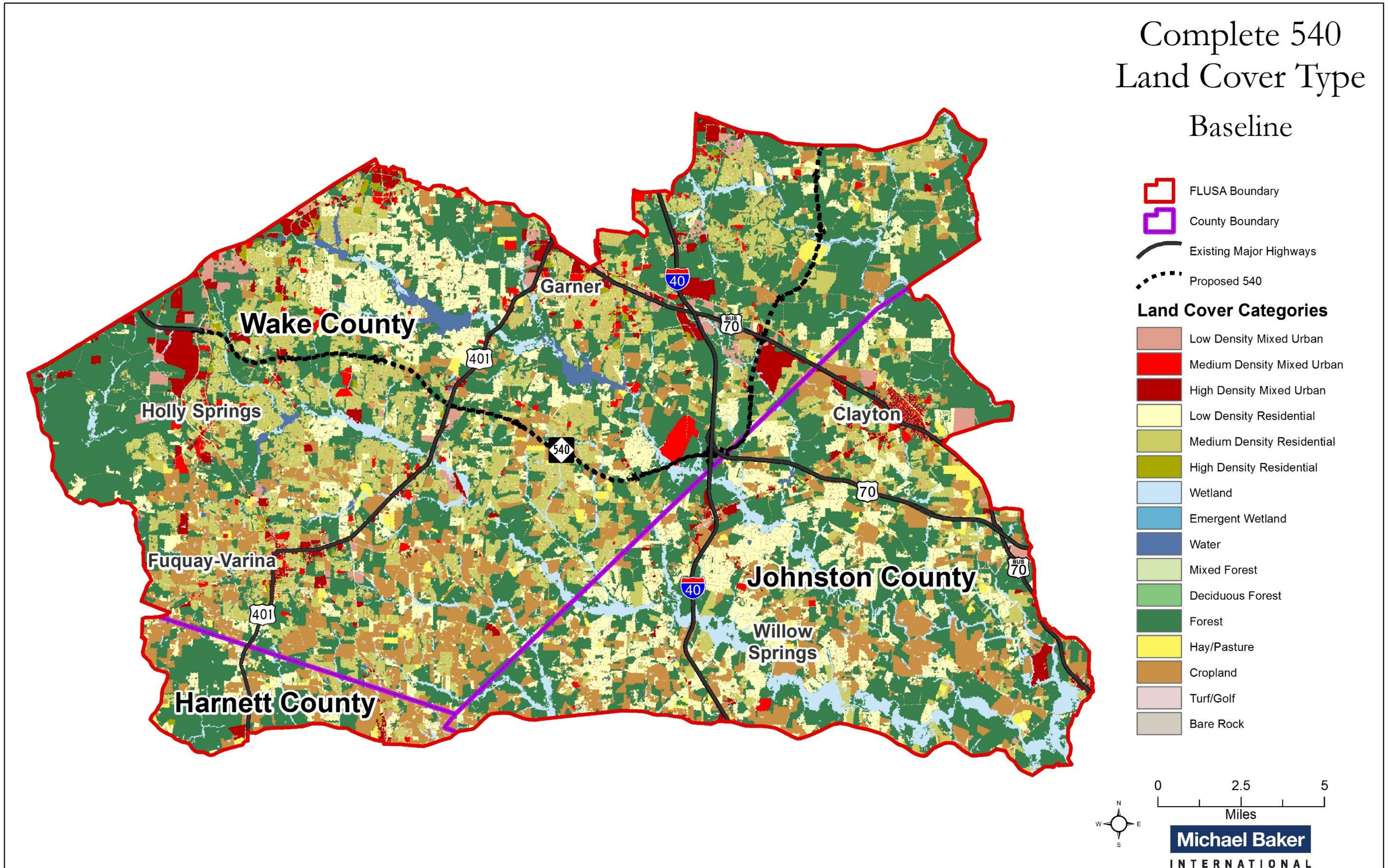
Approximately 110,000 acres, or 39 percent, of the FLUSA is developed (i.e., assigned to one of the mixed urban or residential Land Cover Categories or the Turf/Golf Land Cover Category). About 169,000 acres, or 61 percent of the FLUSA is undeveloped, cropland, or water.

Table 4: Baseline Scenario Land Cover Results

Land Cover Code	Land Cover Category	Acres	Percent of Total Area
2	Low Density Mixed Urban	11,191	4
20	Medium Density Mixed Urban	3,906	1
3	High Density Mixed Urban	8,608	3
17	Low Density Residential	42,975	15
18	Medium Density Residential	41,208	15
19	High Density Residential	1,345	>1
16	Turf/Golf	939	>1
4	Hay/Pasture	4,037	1
5	Cropland	40,150	14
7	Forest	105,190	38
8	Mixed Forest	707	>1
9	Deciduous Forest	181	>1
10	Wetland	15,770	6
11	Emergent Wetland	8	>1
22	Bare Rock	66	>1
1	Water	2,378	1
Total		278,658	100[1]

[1] Sum of the parts does not equal the total due to rounding of each group.

Figure 3: Baseline Scenario Land Cover



4.2 2040 No-Build Scenario

Table 5 shows the land cover results for the 2040 No-Build scenario. This reflects the forecasted land cover in the FLUSA in 2040 if Complete 540 were not constructed. Figure 4 shows the land cover in the 2040 No-Build scenario within the FLUSA.

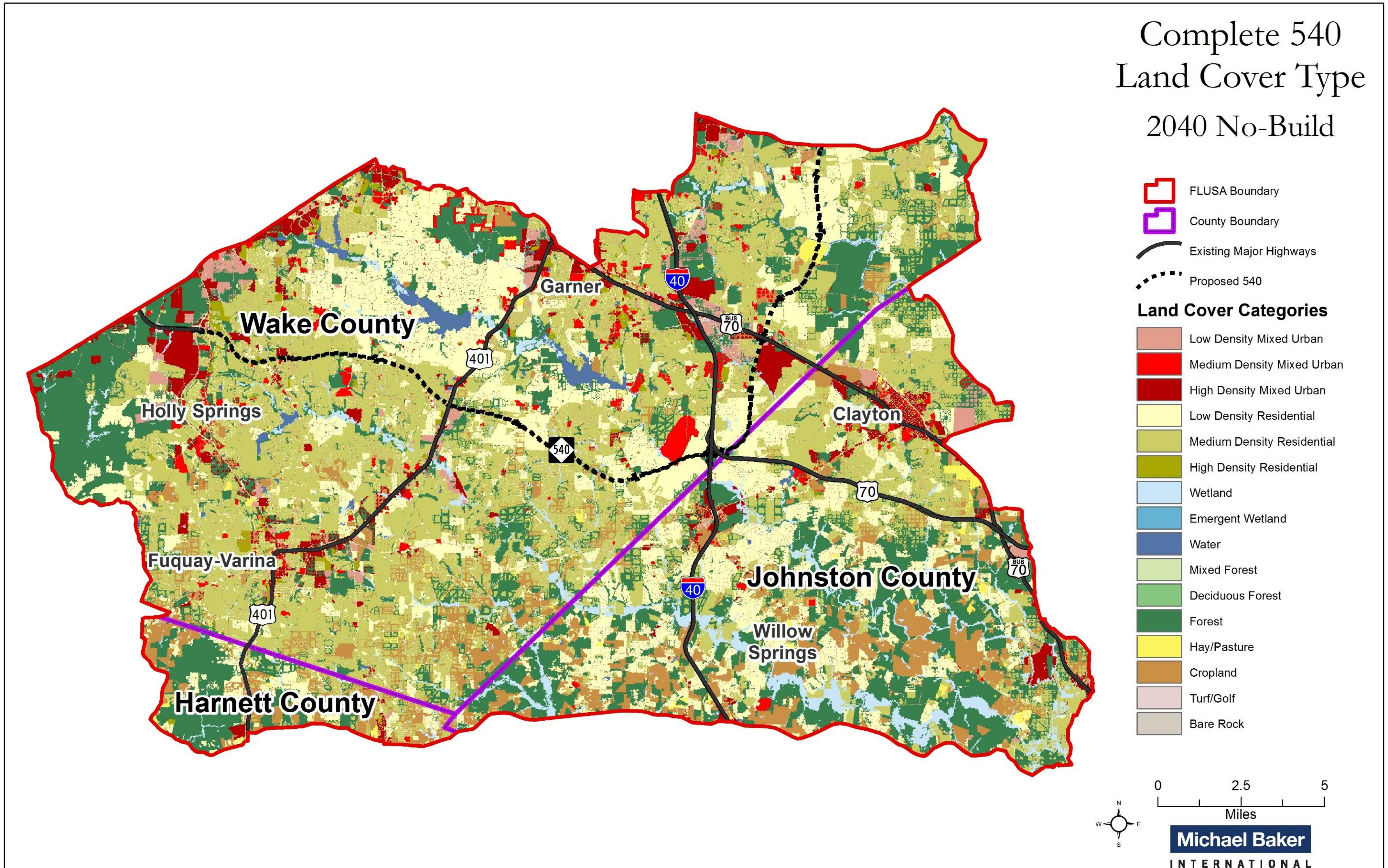
This scenario assigns approximately 183,000 acres, or 66 percent, of the FLUSA to a developed Land Cover Category (i.e., one of the mixed urban or residential categories, or Turf/Golf). About 96,000 acres, or 34 percent of the FLUSA would be undeveloped, cropland, or water under this scenario.

Table 5: 2040 No-Build Scenario Land Cover Results

Land Cover Code	Land Cover Category	Acres	Percent of Total Area
2	Low Density Mixed Urban	11,518	4
20	Medium Density Mixed Urban	5,251	2
3	High Density Mixed Urban	10,706	4
17	Low Density Residential	59,989	22
18	Medium Density Residential	92,431	33
19	High Density Residential	2,014	1
16	Turf/Golf	833	>1
4	Hay/Pasture	2,434	1
5	Cropland	22,627	8
7	Forest	57,620	21
8	Mixed Forest	577	>1
9	Deciduous Forest	151	>1
10	Wetland	10,134	4
11	Emergent Wetland	6	>1
22	Bare Rock	51	>1
1	Water	2,317	1
Total		278,658	100[1]

[1] Sum of the parts does not equal the total due to rounding of each group.

Figure 4: 2040 No-Build Scenario Land Cover



4.3 2040 Build Scenario

Table 6 below shows the land cover results for the 2040 Build scenario. This reflects the forecasted land cover in the FLUSA in 2040 if Complete 540 were constructed. Figure 5 shows the land cover in the 2040 Build scenario within the FLUSA.

This scenario assigns approximately 184,000 acres, or about 66 percent, of the FLUSA to a developed Land Cover Category (i.e., one of the mixed urban or residential categories, or Turf/Golf). About 95,000 acres, or 34 percent, of the FLUSA would be undeveloped, cropland, or water under this scenario.

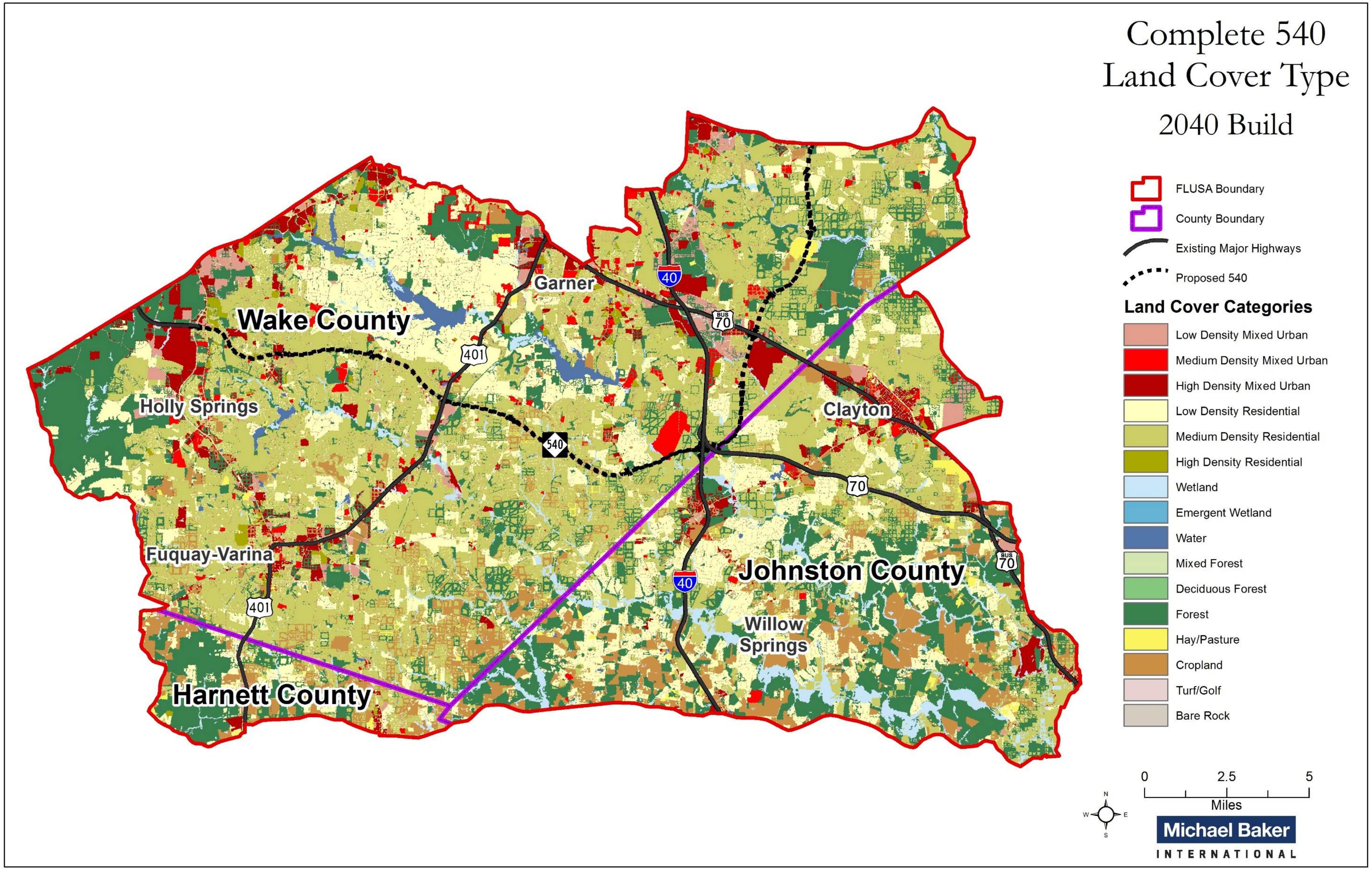
Table 6: 2040 Build Scenario Land Cover Results

Land Cover Code	Land Cover Category	Acres	Percent of Total Area
2	Low Density Mixed Urban	12,248	4
20	Medium Density Mixed Urban	5,293	2
3	High Density Mixed Urban	11,009	4
17	Low Density Residential	52,287	19
18	Medium Density Residential	100,494	36
19	High Density Residential	2,028	1
16	Turf/Golf	816	0
4	Hay/Pasture	2,336	1
5	Cropland	22,027	8
7	Forest	57,287	21
8	Mixed Forest	530	0
9	Deciduous Forest	139	0
10	Wetland	9,782	4
11	Emergent Wetland	7	0
22	Bare Rock	50	0
1	Water	2,324	1
Total		278,658	100[1]

[1] Sum of the parts does not equal the total due to rounding of each group.

Comparing the forecasted 2040 No-Build scenario results to the 2040 Build scenario results, just over 1,400 additional acres are developed, which is less than 1% of the FLUSA. A detailed comparison of the two land development scenarios and assessment of indirect land use effects will be provided in ICE Memo #4.

Figure 5: 2040 Build Scenario Land Cover



5. Impervious Surface Results

The impervious surface coverage was estimated from the land cover estimates for each scenario and was used in the water quality modeling described in Quantitative ICE Memo #3. The water quality model Generalized Watershed Loading Function – Enhanced (GWLF-E) was used to analyze contaminant loadings, baseflow, and runoff at the 12-digit Hydrologic Unit Code (HUC) watershed level. The study area for the water quality model is slightly smaller than the FLUSA because seven HUCs or portions of HUCs along the fringes of the FLUSA were excluded from the study area. The areas of these seven watersheds located within the FLUSA are so small that modeling data for these areas would present data quality concerns. Additional information about the GWLF-E model and the water quality modeling process and results are available in Quantitative ICE Memo #3.

The GWLF-E model was run twice for each scenario to estimate a range of likely indirect and cumulative impacts to the water quality study area. For all model runs, the process described in Sections 2 through 4 of this memo was used to estimate land cover in the water quality study area. The first model run used the land cover results and the GWLF-E (the model) default values to convert land cover results to percent impervious coverage for each HUC in the study area. The model's default values represent national averages for percentages of impervious surface cover; therefore, the defaults would be a conservative estimate (one that may overestimate impervious cover percentages for land use types and land cover categories).

Based on a review of existing land cover and land use regulations currently adopted by local communities, the existing percentages for impervious surface by land cover type in the FLUSA are lower, as shown in Table 7. For this reason, a second model run was conducted using percent impervious estimates that were specifically calculated based on conditions observed in the FLUSA. The 2010 NLCD data were used to obtain the percent impervious coverage for each land cover type within the water quality study area. The percent impervious coverage by land cover type was then averaged across the water quality study area. The average impervious cover estimate for each land cover type (Table 7) was then applied to the parcels within each HUC to estimate the overall percent impervious coverage under each land use scenario. Although the average percent impervious coverage estimates were derived from observed percent impervious coverage in 2010, the percent impervious cover for the 2010 scenario is a theoretical estimate.

The percent impervious estimates for the 2010, 2040 Build, and 2040 No-Build scenarios were calculated with the same methodology of using averages for the entire water quality study area. The percent impervious coverage estimates by land cover category developed for use in the second model run provide a closer approximation of regulatory limits that currently apply in much of the FLUSA, including open space regulations and impervious surface limits, as discussed in Section 2 of Quantitative ICE Memo #4.

Table 7 shows the percent impervious coverage by land cover type used in each model run. With one exception, the observed impervious surface ratios are lower than the default values from the model for each land cover type. The one exception is Low Density Mixed Urban land cover category, which accounts for a very small amount (approximately 4 percent) of the land cover in the FLUSA. The first model run appears likely to produce higher impervious surface estimates than would be expected in the FLUSA, and the second model run could produce some under-estimation of impervious surface percentages; therefore, Model Run 2 provides a low-end-of-range estimate, and Model Run 1 provides a high-end-of-range estimate. The future results are expected to fall between the values of the two model runs for each watershed.

Table 7: Percent Impervious Coverage by Land Cover Type Used in Model Runs 1 and 2

Land Use Code	Land Cover Category	Percent Impervious	
		Model Run 1 GWLF-E Defaults (Upper Limit)	Model Run 2 Observed Baseline (Lower Limit)
2	Low Density Mixed Urban	15	18
3	High Density Mixed Urban	87	29
17	Low Density Residential	15	9
18	Medium Density Residential	52	12
19	High Density Residential	87	33
20	Medium Density Mixed Urban	52	25

Table 8 shows the Model Run 1 impervious surface estimates for all three scenarios for the water quality study area and all the watersheds therein. Table 9 shows the Model Run 2 impervious surface estimates for all three scenarios for the water quality study area and all the watersheds therein. Figure 6 presents a graphic comparison of the difference in estimated percent impervious coverage by water quality study area and HUC between the 2010 and future scenarios for each model run.

In the water quality study area, estimated impervious surface coverage increases by 12 percent using the Model Run 1 estimation methodology and by 3 percent using Model Run 2 methodology from the 2010 to 2040 No-Build scenarios. Between the 2010 and 2040 Build scenarios, the estimated percent impervious increases by 13 percent for Model Run 1 and by 3 percent for Model Run 2. From the 2040 No-Build to 2040 Build scenarios, estimated impervious surface coverage increases by one percent or less for the entire water quality study area for both model runs. These figures and the corresponding acreage amounts for the Water Quality Study Area are shown in Table 10. In acres, the difference in estimated impervious surface between 2010 and the 2040 No Build scenario is over 32,000 acres and the difference from the 2040 No-Build to the 2040 Build scenario is 3,400 acres in Model Run 1. For Model Run 2, these figures are 8,800 acres from 2010 to the 2040 No-Build Scenario, and 500 acres for the difference between 2040 No-Build and 2040 Build scenarios.

Most watersheds see an increase in impervious surface from the 2010 to 2040 No-Build scenarios, as is consistent with growth projections for the area in most watersheds, with a relatively small incremental increase from the 2040 No-Build to 2040 Build scenarios. Impervious surface coverage is projected to increase by one percent or less from the 2040 No-Build to the 2040 Build scenarios in most watersheds for Model Run 1 and by less than one percent in all watersheds for Model Run 2. In Model Run 1, three percent increases in impervious surface coverage were estimated between the 2040 No-Build to 2040 Build scenarios in Middle Middle Creek, Poplar Creek-Neuse River, and White Oak Creek (Upper). In addition, the estimation method for Model Run 1 projected a 6 percent increase in the Mahlers Creek-Swift Creek watershed from the 2040 No-Build to 2040 Build scenarios. Projected increases in estimated percent impervious coverage were less than one percent in these watersheds for Model Run 2.

Table 8: Upper-Limit Impervious Surface Results for Model Run 1 of the 2010, 2040 No-Build, and 2040 Build Scenarios

Water-shed ID	Name	2010 (%)	2040 No-Build (%)	Difference between 2010 and 2040 No-Build[1] (%)	2040 Build (%)	Difference between 2010 and 2040 Build[1] (%)	Difference between 2040 No-Build and 2040 Build[1] (%)
	Water Quality Study Area	14	26	12	27	13	1
1	White Oak Creek (Lower)	10	28	18	29	20	1
2	Avents Creek-Cape Fear River	4	5	<1	5	<1	<1
3	Hector Creek-Cape Fear River	5	7	2	7	3	<1
4	Camp Branch-Black Creek	6	7	<1	7	<1	<1
5	Neills Creek	16	33	18	33	18	<1
6	Little Black Creek-Black Creek	9	22	13	23	15	1
7	Buckhorn Creek	12	29	17	30	18	<1
8	Lower Middle Creek	8	13	5	14	6	1
9	Reed Branch-Swift Creek	12	21	10	22	10	<1
10	Piney Grove Cemetery-Swift Creek	7	12	5	13	6	<1
11	Middle Middle Creek	16	28	12	31	15	3
12	White Oak Creek (Cape Fear Basin)	14	20	6	20	6	<1
13	Little Creek (Lower)	9	22	13	22	13	<1
14	Upper Middle Creek	22	39	17	39	18	<1
15	Mahlers Creek-Swift Creek	14	29	15	34	21	6
16	Lake Benson-Swift Creek	19	26	7	26	7	<1
17	Lake Wheeler-Swift Creek	21	24	3	24	3	<1
18	Walnut Creek	21	38	17	38	17	<1
19	Poplar Creek-Neuse River	11	27	16	30	20	3
20	Marks Creek	7	25	18	26	18	<1
21	Lower Crabtree Creek	39	40	2	40	2	<1
22	White Oak Creek (Upper)	20	38	18	40	21	3
23	Little Creek (Upper)	25	38	13	38	14	<1

[1] Note: all results are rounded and, as such, may not appear to add/subtract correctly. For example, 1.4% rounds to 1%, while 1.7% rounds to 2%, but the difference between them, 0.3%, would be shown as <1. Note that all figures use the watershed acreage as the denominator and are mathematically comparable (i.e., the difference between the 2040 No-Build and 2040 Build scenarios is the mathematical difference between each scenario's percentage result, as opposed to a relative percentage change from the 2040 No-Build result).

Table 9: Lower-Limit Impervious Surface Estimates for Model Run 2 of the 2010, 2040 No-Build, and 2040 Build Scenarios

Water-shed ID	Name	2010 (%)	2040 No-Build (%)	Difference between 2010 and 2040 No-Build1 (%)	2040 Build (%)	Difference between 2010 and 2040 Build1 (%)	Difference between 2040 No-Build and 2040 Build1 (%)
	Water Quality Study Area	5	8	3	9	3	<1
1	White Oak Creek (Lower)	4	9	5	9	5	<1
2	Avents Creek-Cape Fear River	2	2	<1	2	<1	<1
3	Hector Creek-Cape Fear River	2	3	<1	3	<1	<1
4	Camp Branch-Black Creek	3	4	<1	4	<1	<1
5	Neills Creek	5	10	4	10	4	<1
6	Little Black Creek-Black Creek	3	6	3	7	4	<1
7	Buckhorn Creek	4	8	4	8	4	<1
8	Lower Middle Creek	3	5	1	5	2	<1
9	Reed Branch-Swift Creek	4	7	2	7	3	<1
10	Piney Grove Cemetery-Swift Creek	4	5	1	5	1	<1
11	Middle Middle Creek	5	8	3	9	4	<1
12	White Oak Creek (Cape Fear Basin)	5	7	2	7	2	<1
13	Little Creek (Lower)	4	7	3	7	3	<1
14	Upper Middle Creek	7	11	4	11	4	<1
15	Mahlers Creek-Swift Creek	5	10	5	11	5	<1
16	Lake Benson-Swift Creek	7	10	3	10	3	<1
17	Lake Wheeler-Swift Creek	9	10	1	10	1	<1
18	Walnut Creek	7	12	4	12	4	<1
19	Poplar Creek-Neuse River	4	8	5	9	5	<1
20	Marks Creek	2	7	5	7	5	<1
21	Lower Crabtree Creek	15	16	<1	16	<1	<1
22	White Oak Creek (Upper)	7	13	6	14	6	<1
23	Little Creek (Upper)	9	12	3	12	3	<1

[1] Note: all results are rounded and, as such, may not appear to add/subtract correctly. For example, 1.4% rounds to 1%, while 1.7% rounds to 2%, but the difference between them, 0.3%, would be shown as <1. Note that all figures use the watershed acreage as the denominator and are mathematically comparable (i.e., the difference between the 2040 No-Build and 2040 Build scenarios is the mathematical difference between each scenario's percentage result, as opposed to a relative percentage change from the 2040 No-Build result).

Figure 6: Change in Percent Impervious from 2010 to 2040 No-Build Scenarios and 2010 to 2040 Build Scenarios for Model Runs 1 and 2

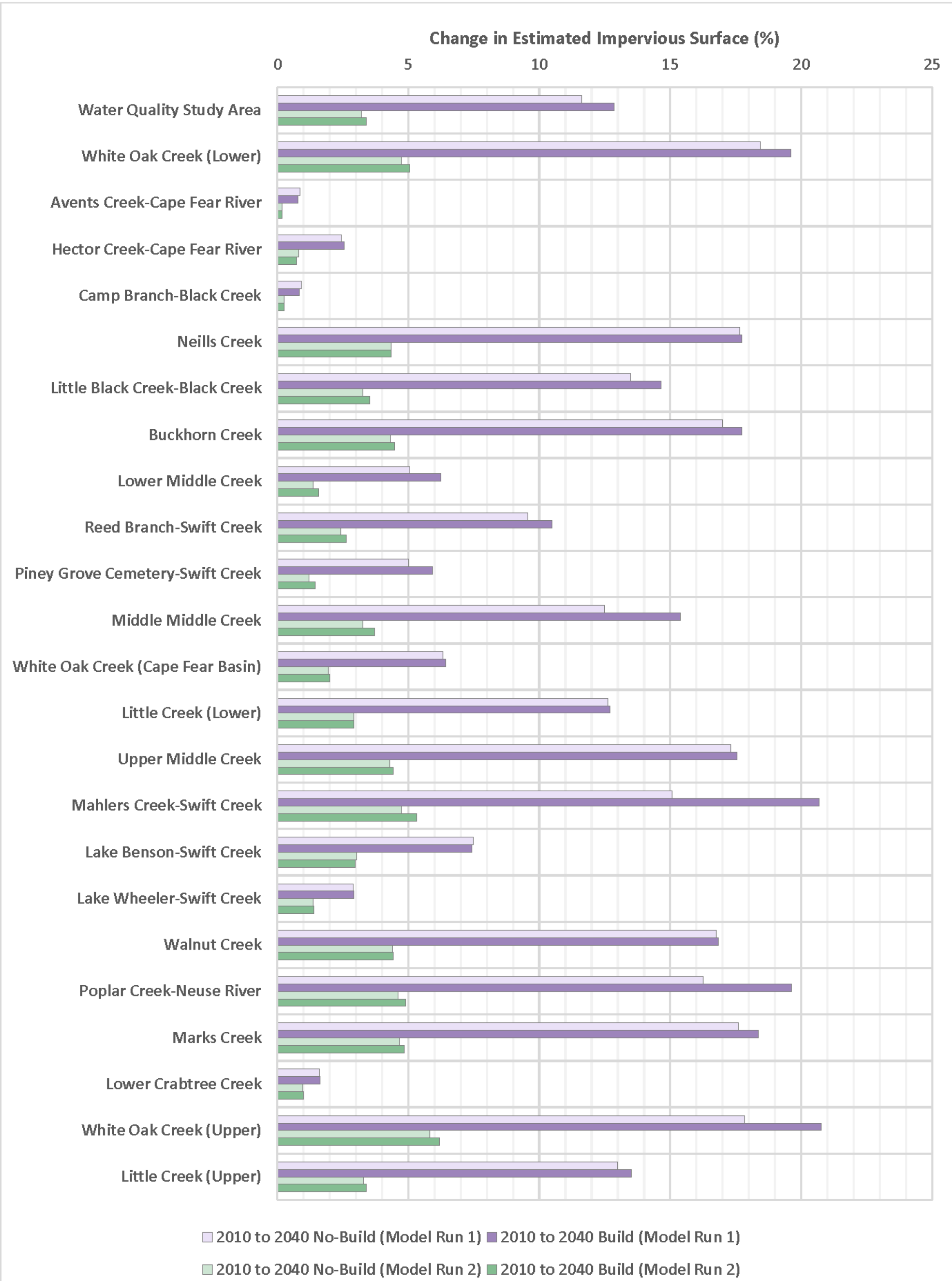


Table 10: Water Quality Study Area Summary Results for Impervious Surface

Model Run and Units	2010	2040 No-Build	Difference between 2010 and 2040 No-Build[1]	2040 Build	Difference between 2010 and 2040 Build[1]	Difference between 2040 No-Build and 2040 Build[1]
Model Run 1 - percentage	14	26	12	27	13	1
Model Run 1 - Acres	38,600	72,000	32,100	75,400	35,500	3,400
Model Run 2 - percentage	5	8	3	9	3	<1
Model Run 2 - Acres	14,600	23,400	8,800	23,900	9,300	500

The Water Quality Study Area (as shown in Figure 2) includes approximately 275,800 acres. The acreages above are based on detailed impervious surface calculations and are not a product of the rounded percentages shown.

Some watersheds show a decrease in estimated impervious surface coverage from the 2040 No-Build to 2040 Build scenarios. These reductions are likely due to changes in the types of development and associated density assigned to the parcels in these watersheds. This finding is consistent with the qualitative ICE documentation provided in the DEIS that indicated the main differences between the No-Build and Build will be the timing, location, and intensity of development. Land use changes associated with the 2040 No-Build scenario are influenced more by the existing (and projected) roadway network without Complete 540, whereas the 2040 Build scenario land use changes include the influence of Complete 540. As explained in Quantitative ICE Memo #1, the CommunityViz model accounts for this influence by utilizing customized inputs for attractiveness factors to forecast future land use.

6. Traffic Analysis Zone-Level Socioeconomic Forecast Results

As part of the CommunityViz model outputs, a new set of TAZ-level socioeconomic data was forecasted for the 2040 No-Build scenario. These data provide estimates of the numbers of households and jobs expected within each TAZ associated with the FLUSA in 2040 under the No-Build scenario. These data will be used to conduct a traffic analysis of possible indirect effects of the proposed highway using the regional travel demand model, the TRM.

The socioeconomic data generated by CommunityViz report households instead of dwelling units. Households are slightly different than dwelling units because some dwelling units may be vacant. The number of households in a TAZ is equal to its number of occupied dwelling units. The number of households (or occupied dwelling units) is more useful information for a travel demand model because vacant dwelling units do not produce travel demand. On the other hand, the number of dwelling units is more useful to land use and water quality studies because even vacant dwelling units affect the environment due to their impervious surface.

- Figure 7 shows the difference in the numbers of households by TAZ between the 2040 Build scenario and 2040 No-Build scenario forecasts.

- Figure 8 shows the difference in the numbers of jobs by TAZ between the 2040 Build scenario and 2040 No-Build scenario forecasts.

In both figures, red hues show areas with fewer households or jobs in the 2040 No-Build scenario compared to the 2040 Build scenario, while blue hues show areas with more households or jobs in the 2040 No-Build scenario compared to the 2040 Build scenario. In other words, the red areas have more households or jobs in the 2040 Build scenario. Those areas have negative values in Figures 7 and 8 because the comparison is presented as the difference from the 2040 Build scenario (which represents the existing forecasts and expected growth) to the newly-derived 2040 No-Build scenario.

Although the changes made to the population and employment control totals described in Quantitative ICE Assessment Memo #1 were limited to only Wake and Johnston counties, the CommunityViz model operates at a regional scale and recalculates attractiveness scores across the region whenever a new model run is completed. In addition, the model incorporates a randomness factor that means even if all inputs are the same, two model runs would result in some differences. Therefore, the maps only highlight TAZs with a difference of more than 20 households or jobs. The patterns of relative increases and decreases of TAZ-level household and jobs illustrate not only the slightly reduced amount of growth projected for the 2040 No-Build scenario, but also a redistribution of growth related mostly to the differences in attractiveness factors.

Using the CommunityViz model results, the induced growth between the 2040 No-Build and 2040 Build scenarios within the FLUSA is approximately 7,000 households and 6,000 jobs. The difference between the 2040 No-Build and 2040 Build scenarios amounts to approximately 5% higher number of jobs and 7% higher number of households in the FLUSA under the 2040 Build scenario compared to the 2040 No-Build scenario.

The map of the differences in households shows that the 2040 No-Build scenario has fewer households in most TAZs along the proposed Complete 540 Preferred Alternative corridor, particularly:

- In the portion between US 401 and US 64/264
- In some TAZs farther from the proposed highway in the general quadrant south and east between US 401 and US 64/264 (I-495)

Some TAZs in the FLUSA gain households in the 2040 No-Build scenario compared to the 2040 Build scenario. Most of these TAZs are in Harnett County and around Apex. One TAZ near US 401 and the proposed Complete 540 and one TAZ near the proposed Complete 540/I-40 interchange also show increases in households. Overall, though, the TAZs with gains in households have much smaller gains than those that have losses when comparing the 2040 No-Build scenario to the 2040 Build scenario. As a point of note, more rural TAZs are larger, but their size does not imply a greater difference in population.

The map of the difference in the number of jobs by TAZ shows that the 2040 No-Build scenario has fewer jobs in TAZs in the FLUSA in three key areas:

- Along the proposed Complete 540 Preferred Alternative corridor

- Along I-40
- Along US 70 east of the proposed Complete 540 Preferred Alternative corridor

Overall, where TAZs gain jobs in the 2040 No-Build scenario, they tend to gain fewer jobs than the TAZs that lose jobs. Again, rural TAZs are larger, but their size does not imply a greater difference in employment.

The 2040 No-Build scenario TAZ-level socioeconomic data outputs will be utilized in the TRM to project future potential traffic conditions for comparison to the 2040 Build scenario as part of the assessment of indirect and cumulative effects.

Figure 7: Change in Number of Households by Traffic Analysis Zone from the 2040 Build Scenario to the 2040 No-Build Scenario

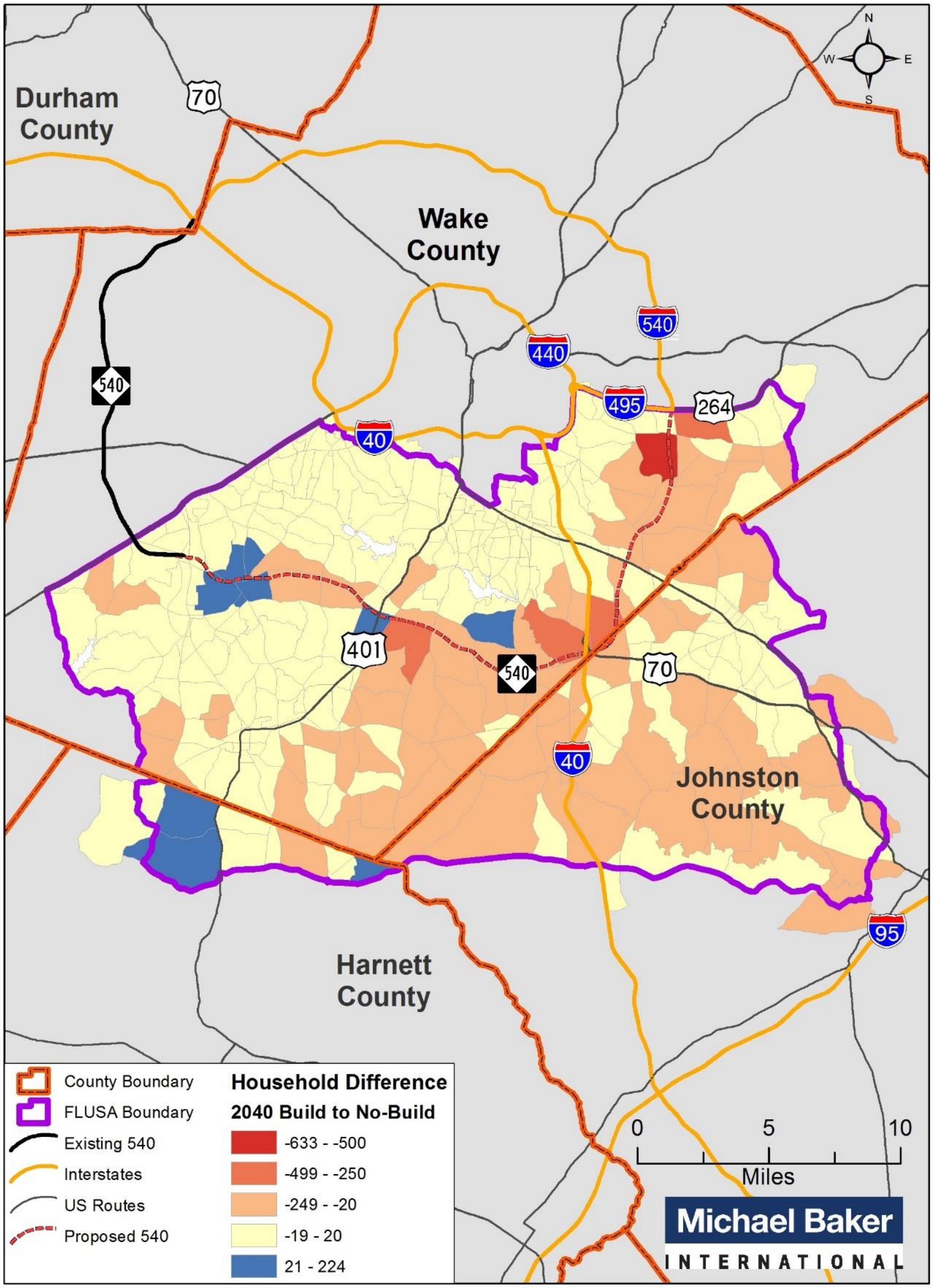
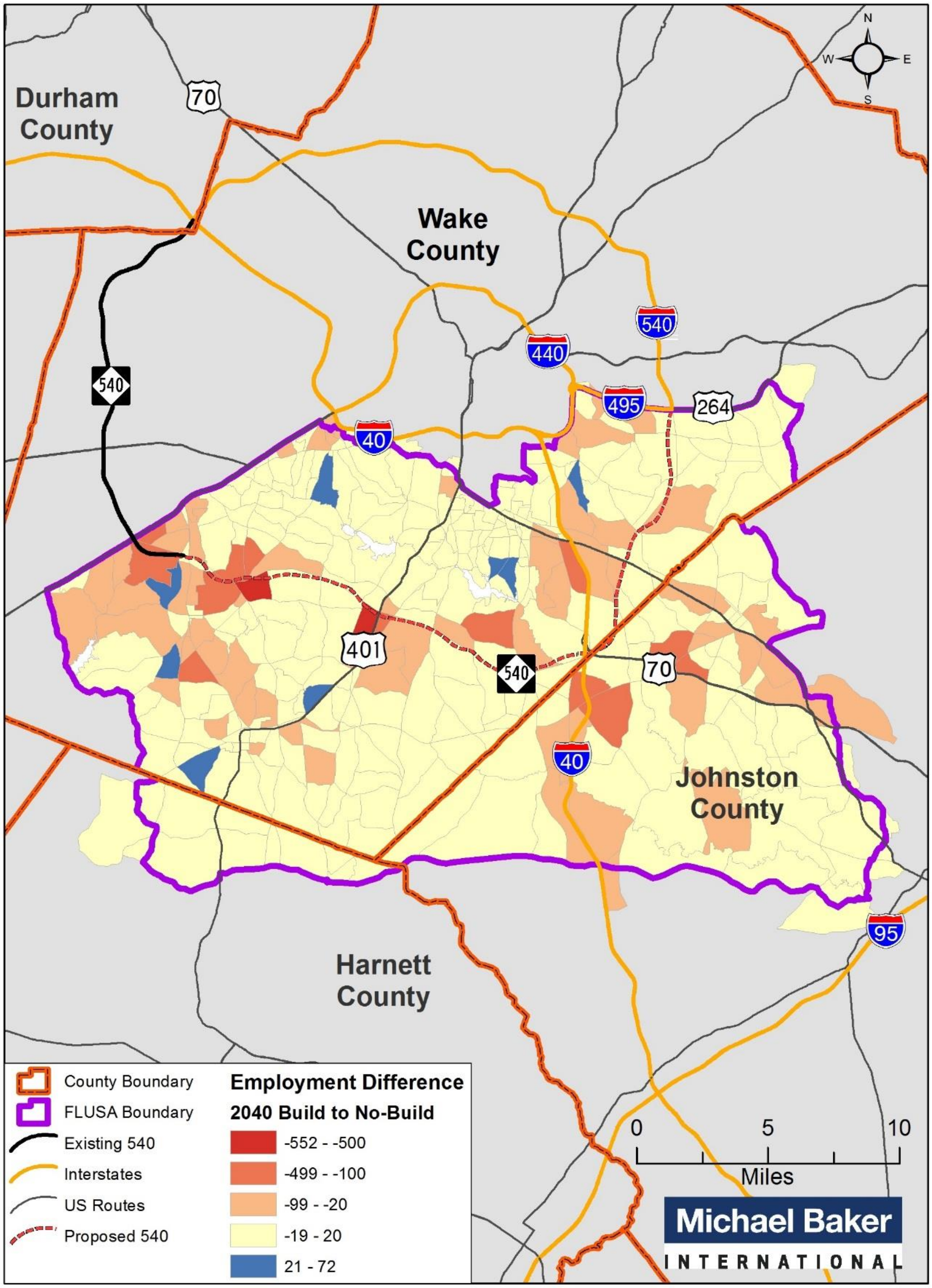


Figure 8: Change in Number of Jobs by Traffic Analysis Zone from the 2040 Build Scenario to the 2040 No-Build Scenario



7. Next Steps

Two steps remain in the Quantitative ICE process.

- Assess the indirect and cumulative water quality effects of the land use differences using the land cover rasters of each scenario and a water quality model to calculate differences in pollutant loading in the FLUSA watersheds.
- Input the 2040 No-Build scenario TAZ-level socioeconomic data outputs into the TRM to project future potential traffic conditions for comparison to 2040 Build scenario projections.

Both of these modeling exercises will help in estimating any potential indirect effects of the proposed project. The outputs will also be used in combination with other information on past, present, and future actions by federal, state, local, and non-governmental entities to assess potential cumulative effects associated with the proposed project. The water quality modeling findings will be documented in ICE Memo #3, the traffic analysis findings will be documented in the ICE Traffic Assessment Memo, and the full discussion of indirect and cumulative effects will be contained in ICE Memo #4.

8. References

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