

Ivy Groundwater Assessment and Mapping

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Abstract— The conversion of rural land from farming and forest cover to uses for housing and commercial development has significant adverse impacts on ecological, environmental, and natural resources. When housing is developed in rural areas without the extension of public infrastructure for water and sewage, these developments must draw on groundwater, mostly from private wells, for their drinking water supply, and use septic tanks with drain fields for their sewage. This type of land conversion is occurring at an accelerated pace in many parts of Virginia, particularly in the City of Charlottesville and surrounding Albemarle County. It is important to know the carrying capacity of the regional groundwater resource in order to ensure that there will be water and septic system absorbing capacity to support current and planned levels of development. Unfortunately County officials do not have information on the availability of regional groundwater resources. As a result, new development permits are granted without information about their long term impact on the availability and quality of the resource on which the majority of private homes depend for their water supply. This project extends the work of a previous Capstone to assess the availability and quality of groundwater from private wells in Albemarle County, and map the results for use by County planners in making decisions about the location and intensity of development across the county. The study draws upon a review of the literature on groundwater assessment, natural resource conservation, smart growth, and collaborative environmental problem solving, including a review of State programs, resources at the Environmental Protection Agency and the US Geological Survey, and a survey of four states in the Blue Ridge geological region. Finding little consistent guidance in the literature on either groundwater assessment methodology, data management, or use of results in decision making, the project developed its own methodology for groundwater assessment using the community of Ivy, in Western Albemarle County as a case study. Groundwater assessment was done using samples from private wells tested with a kit developed by a previous Capstone project. The results were consolidated with data on well construction, flow rate, and water quality, maintained by the Virginia Department of Health, the Department of Mines , Minerals and Energy; and the County Office of Groundwater Resources. The well water assessment results were mapped in ArcGis, and presented to members of a project advisory board for user testing in

decision-making about regional development based on groundwater capacity information. Detailed user testing is planned for members of the County Board of Supervisors, and other representatives of stakeholder groups with an interest in land use in Albemarle County and surrounding areas. The results of this work are expected to serve as a model for natural resource assessment and use in development planning for other communities nationwide confronting the issue of urban sprawl and its impact on rural areas.

I. INTRODUCTION

Urban sprawl is an issue faced by many states which causes stressing on local watersheds. The Ivy Groundwater Assessment project was developed to create a model to determine the quality and quantity of groundwater because no quick, low cost methods and little data on groundwater quality exist at the County level. Land development in the state of Virginia is at an all time high [1]. One local source has noted that, “If Virginia continues to develop land at the current rate, more land will be developed in the next 40 years than was developed in the last 400” [2]. Along with the increase in land development comes a decrease in natural resources and a potential negative environmental impact on groundwater. To insure that land development is consistent with local groundwater carrying capacity tests and surveys must be completed to determine current water quality, potential impact on this quality and soil assessments to determine previous pollution.

Not only does development affect the environment but it also affects local agricultural economies and can cause other environmental and resource problems in local areas [3]. All development decisions must be evaluated on their direct economic impact as well as the economic valuation of their impact on local natural resources. This assessment of groundwater quality and availability in Ivy prepares the preliminary data for later economic evaluation of the impacts of development on local natural resources. The results will ser as a model for other communities similarly faced with the tradeoffs of benefits, costs, and risks of local development.

Local, state, and federal groundwater policies were examined in order to identify any gaps that exist in the Charlottesville/Albemarle groundwater policy. A detailed literature review was conducted and officials from local government offices in VA, MD, NC, and WV were interviewed to assess the state of the art in groundwater assessment and policy in the Blue Ridge region. Additionally, groundwater policies and assessment plans from jurisdictions in Maryland, Indiana, and Washington

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have been reviewed for possible feasibility in the Charlottesville/Albemarle area.

II. BACKGROUND

Groundwater provides almost one-third of the World's water supply [4], and that dependency is expected to increase through the year 2025 [5]. In Virginia, 55 of 95 counties draw over half of their water supply from groundwater sources, and 38 of those are completely dependent on groundwater. Out of 2,500 public water systems in Virginia, 2,300 use groundwater as their source [6]. Because of the importance of groundwater as a source of drinking water in Virginia, it is important to conserve the resource, both in availability and quality.

Groundwater supply and quality has become an issue of concern in many developing rural areas such as in the Ivy area of Albemarle County. The large growth rate being experienced in the region and the heavy reliance on groundwater could stress the resource. The consequences of overtaxing the groundwater supply pose a problem for the future growth in the area, as there is no thoroughly enforced federal policy regarding residential planning for sustainable groundwater availability and quality when it is consumed by the aggregation of individual private homes, as is the case in the Charlottesville/Albemarle area. The majority of households in 60 Virginia counties draw water from private wells, and 92% of these homes also use septic systems for waste disposal [6], even though septic systems "impact the community through groundwater pollution" [7]. Pollution from septic tanks, runoff from agriculture and impervious surfaces, and leaking fuel tanks are the most likely sources of pollution of groundwater in rural areas. Ivy Road is a rapidly developing rural area that is subject to all of these risks. Therefore, knowledge of the quantity and quality of the area's groundwater is important.

With such a dependency on a resource under a pollution threat from septic tanks [7], [8] and fertilizer run-offs, there must be methods of ensuring groundwater quality. Currently in Albemarle, wells are tested when they are drilled by sending the samples to a certified lab. This is a costly and time-consuming process, and is used in part for the real estate transaction and to acquire a building permit from the State Health Department [9]. After this initial testing, wells are not re-sampled or flow rates monitored. Thus any deterioration in the quality or availability of groundwater consumed by the homeowner goes undetected if there is no major case of illness. As a measure of protection, some homeowners who are able to afford it install treatment systems for their well water. This is also a costly option, whose cost is borne by the individual homeowner, and does not address the larger question of conservation of groundwater quality or availability. Our proposed solution incorporates a portable testing kit developed by a team of five systems

engineering students in 2006. Albemarle/Ivy Subdivision was chosen as a test site not only because of close proximity to the University, but also because the rapid population growth witnessed in the county has led to a great deal of development on the urban fringe, resulting in high dependency on wells and septic systems.

The water sampling kit consists of a laptop with USB connectors, probes for each pollutant, and a GPS receiver. The total cost to build the kit was about \$600. This is a one time cost unlike the current water assessment processes used by testing labs on the developer's behalf. To model the groundwater assessment system, water from private wells in southern Ivy were tested for pH and Nitrate concentration. Tests were only performed on houses with no water treatment system. The GPS coordinates of each well were also recorded at the time the water sample was withdrawn in order to facilitate mapping of the results in ArcGIS. The final product is a website that displays the maps of sampled well water quality (for pH and nitrate), along with links to other sources of information on groundwater quality, availability, and importance. The model of groundwater assessment, information management and display could serve as a visual tool to assist decision makers in planning for local development in a way that is informed by the viability and quality of local groundwater resources.

III. VALUING GROUNDWATER AND SEPTIC SYSTEMS IN IVY

A. *The Value of Groundwater at Current Consumption*

In order to assess how the water in the Ivy neighborhood is valued, a starting value was needed. In order to compute this, it was necessary to compute all the costs associated with installing, operating and maintaining a private well. Main research would be found from speaking with companies associated with installing and maintaining wells. Necessary costs include the drilling per foot cost of the well and the PVC casing cost per foot. The purpose of the casing is to provide structural integrity to the well near the surface. There is also a grout charge to be included, to protect the water in the well from potential contaminants. The amount of grout needed depends on the distance from a septic tank or other possible pollutants. Finally, there is the cost of purchasing and installing a pump for the well. Because pumps wear out over time, there would also be a pump replacement cost and the cost of operating the well on a daily basis [10].

Once these costs have been determined, it is possible to create a model to evaluate both the fixed costs of installing a well and the variable costs of operating and maintaining the well. While the fixed costs require no present value computations, the cost of replacing a pump would be discounted annually over the life of the well using the current discount rate. If estimated operating

costs for wells, which are typically only the cost of providing electricity to the pump, are unavailable, it is possible to estimate the cost of pumping water by determining the electricity required for average pumps, usually 1 to 1.5 horsepower.

After establishing all of these costs and discounting the future fixed costs it is possible to get a total cost for operating a well. The metric to be used in evaluating groundwater will be dollars per thousand gallons. Using estimates from the Health department for groundwater consumption on a monthly basis, it is possible to determine the cost per thousand gallons of supplying a resident with groundwater from a private well. Since these are the costs associated with supplying residents with groundwater, this method demonstrates how water is currently valued in the Ivy subdivision of Albemarle County.

B. Determining an Accurate Value of Groundwater

After an initial value was found, it is necessary to compare it against some other value to determine an accurate price for the groundwater in Ivy. This value is the cost of providing the same residents with public water. As stated earlier in the literature review, a method to value a resource such as groundwater is to take current costs and see how a condition change would change the price. The condition change used here is the degradation of a water supply beyond consumption limits, so that residents can no longer use private wells as a source of water. Under this scenario, either the County or the current residents would have to pay for water supply, as they did in Nelson County, Va. [11]. Using this method, it is possible to determine both the infrastructure costs of adding this area to the public water supply and the costs to the residents of public water.

To determine the infrastructure costs of providing water service to the Ivy subdivision, two main costs would have to be determined. First, the cost of laying the actual pipes, etc. to provide water to these houses. Second, the costs of connecting these houses to public water supply. To get a cost estimate for laying pipes and infrastructure, this researcher spoke with a Charlottesville residential property developer, who provided him with a cost per linear foot estimate. Then, he worked with his advisors to estimate the distance the test area is from current infrastructure. South Ivy is our current testing area, and will be the subdivision used for this project.

Using our GIS, or Geographic Information System, software, we can use current infrastructure overlays and a map overlay to estimate distances to the test area. By multiplying the cost per foot of extending the water supply, an estimate of the cost to extend water supply infrastructure can be reached. Using the connection costs provided by the Albemarle County Service Authority (ACSA) and the number of houses that are in the Ivy Subdivision, an accurate estimate of the cost of

connecting South Ivy to public water service can be reached.

After calculating the sunk cost of connecting South Ivy, the other necessary cost would be the cost of obtaining water for resident, also known as the production cost. To find this price, the researcher once again spoke with the ACSA. They provided him with a cost function per thousand gallons. Using this average cost to the consumer in conjunction with average consumption per month estimates provided by the ACSA, it is possible to calculate monthly production cost for water consumption.

Comparing these costs to the current costs, i.e. the cost of private wells, will give an accurate picture of the state of water in western Albemarle County. The assumption, after reviewing current literature, is that the water is most likely undervalued and that the cost of supplying residents with public water supply will greatly exceed the cost obtaining water through private wells.

IV. POLICY AND BEST PRACTICES

Before results can be provided, it is important to know the current state of the groundwater policy with respect to Charlottesville/Albemarle; therefore, the federal, state (Virginia), and local (Charlottesville/Albemarle) groundwater policies will be reviewed here. On the federal level, "federal agencies are engaged in many prevention, detection and correction activities related to groundwater quality, and many different statutes address sources of groundwater contamination. [12]. Despite the involvement of many federal agencies, most importantly the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and the U.S. Geologic Survey (USGS), no one overarching piece of policy exists to protect groundwater. Groundwater policy has been a set of fragmented efforts by numerous agencies and programs [12].

On the state level in Virginia, two pieces of legislature control the state's groundwater policy. The first Virginia law, 15.2-2223, states that a comprehensive plan must be prepared and adopted. This mandates local planning commissions to prepare and recommend plans for the development of areas within its governing power. Under this law a provision states: "The designation of areas for the implementation of reasonable ground water protection measures." The next Virginia Law, 15.2-2224, states that surveys and studies must be conducted in preparation and prior to implementation of the plan. Some other Virginia related groundwater items are the Ground Water Protection Steering Committee and Virginia's Wellhead Protection Program [13]. The steering committee is a collaborative effort between agencies across the state. This committee was created to stimulate, strengthen, and coordinate ground water protection activities in the Commonwealth. The Wellhead Protection Program was

approved by the Environmental Protection Agency on May 26, 2005; the approval meant that protection of ground water based public water supplies will be achieved through the efforts of regulatory and non regulatory state programs and voluntary participation by local governments [13].

Locally, the Charlottesville/Albemarle area has the Albemarle County Groundwater Protection Ordinance from Dec 8, 2004. This states that "...to promote the long-term sustainability of groundwater resources by requiring that certain land development approvals (building permits, subdivision plats, site plans) and central water supplies that will rely on privately owned wells... be subject to a groundwater assessment... Satisfactorily completing the applicable requirements of the groundwater assessment would become a prerequisite to the land development approval" [14]. Though this states that completing applicable requirements of a groundwater assessment are prerequisites to gain approval for land development, neither the Planning Commission nor county staff has the authority to reject on the basis of data from these groundwater assessments. The groundwater assessments conducted can only be used as recommendations to provide possible homeowners for new developments with proper information towards protecting themselves and groundwater resources. A very important piece of legislature hindering local groundwater policy is, Virginia law does not allow for the denial of a building permit based on the supposed impact on neighboring wells. Furthermore, current homeowners do not have priority to groundwater over a property owner wanting to build a new home (i.e. developers wishing to build new subdivisions).

A. Local Policy Gap Analysis

From the information provided about federal, state, and local policies, one would be lead to believe that an adequate set of legislature is in place to sufficiently protect groundwater resources, but for whatever reason this is not the case. This subsection will outline reasons for the holes that exist in the local level, preventing the successful enforcement of groundwater related policy.

As stated above, Virginia law does not allow for the denial of a building permit based on possible impact on neighboring wells [14]. This is problematic for current homeowners in areas identified for further expansion, as they have no priority right to the water in that area whether or not negative impacts are a possibility. Graduate research assistant Aldrich Castillo conducted several interviews with local officials that revealed some important information with respect to groundwater dealings in the area. An official from the Department of Mineral Resources (DMR) which is under the larger DMME revealed that the responsibility for collecting groundwater data has been passed to different agencies over the years. Now, the DMME is no longer responsible for groundwater information, rather it is concerned with

the overall geology of Virginia, so it is still concerned with the impacts of development in the area. Karen Hostetler also pointed out that groundwater information is collected by different agencies based on the type of use for the well. This difference has lead to what is currently a groundwater database with poor integrity, as many duplicate entries exist as efforts to consolidate occur, and the scattering of information across agencies. An official from the Virginia Department of Health (VDH), described the process a homeowner takes to obtain a permit to drill a well. The process is as follows, a driller must identify a spot on the land to drill, the well is drilled and a well completion report is filed with the VDH, then the well completion report and water sample from the new well are submitted to test for compliance with drinking water standards. Once the submission is made and the water is certified, no regulation is in place for subsequent testing of the well; however, Jeff McDaniel noted for transfer of ownership, banks require testing. Testing in this area laid the foundation of the capstone project and for this thesis. The next section of results will go over findings of how other areas are dealing with groundwater.

V. CALCULATIONS OF WATER USAGE RATES AND GIS MAPPING

This section mainly discusses the research and methods used to calculate estimates for water usage rates of private wells in Albemarle County. The first step to calculating the water usage rate was to collect census data and population projections for Albemarle County. There was, however, a discrepancy in the 2000 census between the records of the Census Bureau and the records of Albemarle County. As advised by the Thomas Jefferson Planning District Commission, the census data provided by the county for 2000 was considered the correct number. Also collected from the Census Bureau was data outlining the persons per household for 2000.

The next step was to collect the number of public water connections for the year 1990-2006 to be used as a basis for future connections. The FORECAST() function in excel was used to calculate projections for the number of public water connections through the year 2030. Using this data and the census information on persons per household, an estimate for projected population using public water was determined. This data was the foundation to calculate estimates for the population using private wells. Once all of the population data was calculated, the standard water usage per person estimated to be 100 gallons/day by B & B Consultants. Using this estimate for gallons/day and the estimates for the population using private wells, the usage of water from private wells was determined.

Using the data collected and GIS information from the Thomas Jefferson Planning District Commission maps were created depicting change in population, projected

population and water usage rates. Dot maps were used to show the dispersion of population within the county. Fig. 1, shows the growth between 1990 and 2000. The red dots represent the 1990 population and the green dots represent the growth that occurred from that time until 2000. Fig. 2 displays the projected populations for 2010, 2020, and 2030

Using the data for population projections a map was created to show projected water usage. The maps range from 2000 – 2030 in ten year periods. The maps are broken down into block groups for the county. Fig. 3 displays these projection maps with dark blue being the areas with the largest projected usage rates. These results are discussed in Section VI.

VI. RESULTS

This section will go over the findings from the three different parts of the project: land development, economic value of groundwater, and groundwater with respect to policy.

A. Land Development

In order to calculate the results, assumptions had to be made. The projections for public water connections and population were assumed to have a similar growth rate as the past, therefore, the FORECAST() method was used in Excel for those calculations. The FORECAST() method “calculates, or predicts, a future value by using existing values” [15]. Also by not having a specified number of persons per household after the year 2000, the value used for predictions was assumed to be approximately the same. Lastly, in order to calculate the projections, we assumed that approximately 100 gallons per day per person of water would be used.

Table 1 depicts the calculated results which show that the estimated usage rate for private wells increased from 1990 – 2000 by 300,297 gallons per day. For 2001 – 2003, there was an increase in public water use which resulted in decreased demand for private well usage, and from 2003 – 2005, the usage rate continually increases. This data is displayed in Table 2. The calculations from the FORECAST() method show that the estimated usage rate for private wells increases continually based off of the population projections for 2006 – 2030 and are shown in Table 3. This data shows that there is approximately a 117,450 gals/day increase in the estimated usage rate for private wells every 10 years.

The maps showing population change and water usage rate projections can be used by developers to determine areas with a denser population, areas with a large increase in population growth, and areas which are projected to have possible water stressing in the future. The areas directly around the City of Charlottesville have the densest population and the greatest population growth. Areas directly north and west of Charlottesville show

dense populations and large growths. Fig. 4 also shows that the block groups in the northern part of Albemarle County have the greatest usage rates.

B. Economic Value of Groundwater

A current value for groundwater found in South Ivy was obtained using the methodology described in the previous section. The rate used to discount replacement pump is the current 10-year Treasury bill rate of 4.61%, according to Bloomberg.com. The pump was discounted over ten years because that was the average lifespan noted by C.R. Moore Company. Although well depth and casing depth varies well to well, the depths noted above were listed as averages from C.R. Moore Company. The grout charge can be either \$250 or \$750, depending on the distance from the septic tank, but Laney Moore noted that the charge is usually \$750 in the Ivy subdivision [10]. No treatment costs were included because most residents in Ivy do not use a treatment system. The price for water is increasing non-linearly. For up to three thousand gallons, the price is \$3.37 per thousand gallons, but for an additional thousand gallons, it is \$4.04.

It was possible to calculate the total connection costs to public water. The fixed costs for installing public water supply infrastructure can be compared to the cost of installing a private well. Referring to table 4, it is clear that it is much more expensive to provide public water services than to drill private wells. Yearly costs were compared for comparing water with results shown in Table 5.

In order to assess a value to the water, the average consumption rates for a household needed to be obtained. B & B Consultants notes that an average person consumes 100 gallons of water a day (2007). Census information states that Albemarle County averages 2.44 people per household, and the ACSA uses a number of 2.5 people [16]. In this model the number of 2.5 will be used because it agrees with ACSA data. Using that estimate, it is possible to calculate a per thousand gallon value of water.

Because of new regulations and laws passed, the price of public water is expected to increase by 12% each year for the next five to ten years [16]. According to their website, Dominion Power expects about a 4% increase in the price of electricity, which is the only cost to run a pump on a private well [17]. These increases will be factored into the calculations in the following section.

C. Best Assessment Practice Sites

The evaluation of several types of water resources sites provided a lot of information relating to what should be included in a good model groundwater assessment site. The goal of the Albemarle Groundwater Assessment capstone of developing an effective model that is useful

to county officials and the public in planning for development shed light on the important aspects to focus on prior to collecting information. With this goal in mind, observing the different groups' visual displays of information would be the most important feature for future emulation in the project. Displays from California's Department of Water Resources, the Department of Ecology in Washington State, and the Indiana Department of Natural Resources yielded one constant. This constant was time series displays of groundwater data. Though these programs are not necessarily regulatory in nature, the manner in which their data is displayed would be the most beneficial to a decision maker.

For the creation of the Albemarle Groundwater Assessment (AGWA) site, emulation occurred in multiple areas. Consistent throughout the other organizations' sites was resources, this ranged anywhere from local or state ordinances, how-to guides for obtaining permits or testing your water, to contact information. The AGWA project site emulated these findings through a compilation of numerous local and state resources for potential users of the site. A good groundwater resource page is one that keeps its users informed, so the key to providing this is an abundance of resources. For the sake of homeowners and decision makers, who may not be as well versed technically as those performing the studies, summaries of all the reports and displays should be provided for their use. The AGWA page has begun this process by including minutes and reports from already completed work and meetings.

Best Assessment Practice: Policy Related Findings

As seen in Virginia, the work done by many agencies outside of Virginia is not regulatory in nature. The work however is done for a client who may wish to change regulatory policy, change a permit, take regulatory action, or not do anything at all. From correspondence with an official of the Environmental Assessment Program in Washington's Department of Ecology and of the California Department of Water Resources, the work of their organizations is not regulatory which allows them to be as objective as possible in obtaining and presenting results to their clients. In California, an official described how the data collection leads to modeling studies which are then used to aid decision makers. In Washington, the studies are conducted by the Environmental Assessment Program (EAP); it is focused completely on technical services, as they do not make or enforce regulations. The work they do is to assist other programs, who are their "client;" they hire the EAP to conduct technical studies to answer questions or resolve issues pertaining to problems or concerns they encounter in the course of conducting their regulatory work.

From discussion with groundwater officials in other offices, it seems that groundwater policy itself is not an issue per se. As seen in Charlottesville, with local officials struggling to enforce the policy, what seems to be the problem is not a weak policy or lack thereof, but

rather a poor framework in which that specific policy operates. Initial beliefs were the lack of policy or gaps in policy were the reason behind the problem, but discussion with local and other state groundwater officials have revealed that a stronger groundwater assessment program and data management system would.

VII. CONCLUSION

With the importance of groundwater to rural areas such as Albemarle, a study such as this one will be important to ensure that policy makers are well informed so that they can make sustainable development decisions. With the expected increase in water usage rates over the next ten years, groundwater sources will be under a higher stress. The increasing prices of water for both public and private supply will increase the cost to consumers. The review of policy gaps has shown that cities such as Charlottesville need accurate groundwater data to put in place strong programs of conserving groundwater in order to provide a safe water supply for generations to come. Our group was able to determine these rates and values, as well as reviewing public policy in Albemarle County.

Since this is an ongoing project, it will be important for future groups to continue the testing and mapping of private wells in Albemarle County. A more in depth study of both consumption rates and economic values will be necessary in the future to see how current changes are affecting the market.

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APPENDIX

Tables

Year	Population	Public Water connections	Persons per household	Pop. on private water estimate	Gallons per day per person	Estimated Usage Rate Private Wells
1990	68,040	8,395	2.79	44,618	100	4461795
2000	79,236	12,957	2.44	47,621	100	4762092

Table 1: Calculations Provided by the Author for the Estimated Usage Rate for Private Wells

Table 2: Calculations Provided by the Author for the Estimated Usage Rate for Private Wells Based on Population Projections by the Census Bureau

Year	Pop Projections	Public Water connections	Persons per household	Population using private wells (estimate)	Gallons per day per person	Estimated Usage rate Private Wells
2001	85,750	13,410	2.44	53,030	100	5,302,960
2002	86,461	13,800	2.44	52,789	100	5,278,900
2003	87,654	14,304	2.44	52,752	100	5,275,224
2004	89,017	14,684	2.44	53,188	100	5,318,804
2005	90,717	15,187	2.44	53,661	100	5,366,072

Table 3: Calculations Provided by the Author for the Estimated Usage Rate for Private Wells Bases on Population Projections Created by Excel

Year	Population Projections	Public Water connections	Persons per household	Population using private wells (estimate)	Gal per day per person	Estimated Usage Rate Private Wells
2006	91,667	15,685	2.44	53,395	100	5,339,540
2007	92,916	16,123	2.44	53,575	100	5,357,529
2008	94,165	16,587	2.44	53,693	100	5,369,274
2009	95,414	17,051	2.44	53,810	100	5,381,019
2010	96,663	17,514	2.44	53,928	100	5,392,764
2011	97,912	17,978	2.44	54,045	100	5,404,509
2012	99,161	18,442	2.44	54,163	100	5,416,254
2013	100,410	18,906	2.44	54,280	100	5,427,999
2014	101,659	19,369	2.44	54,397	100	5,439,744
2015	102,908	19,833	2.44	54,515	100	5,451,489
2016	104,157	20,297	2.44	54,632	100	5,463,234
2017	105,406	20,761	2.44	54,750	100	5,474,979
2018	106,655	21,224	2.44	54,867	100	5,486,724
2019	107,904	21,688	2.44	54,985	100	5,498,469
2020	109,153	22,152	2.44	55,102	100	5,510,214
2021	110,402	22,616	2.44	55,220	100	5,521,959
2022	111,651	23,079	2.44	55,337	100	5,533,704
2023	112,900	23,543	2.44	55,454	100	5,545,449
2024	114,149	24,007	2.44	55,572	100	5,557,194
2025	115,398	24,471	2.44	55,689	100	5,568,939
2026	116,647	24,934	2.44	55,807	100	5,580,684
2027	117,896	25,398	2.44	55,924	100	5,592,429
2028	119,145	25,862	2.44	56,042	100	5,604,174
2029	120,394	26,326	2.44	56,159	100	5,615,919
2030	121,643	26,789	2.44	56,277	100	5,627,664

Table 4: Fixed Costs of Water Supply for South Ivy

	Public Water	Private Well, No Treatment
Fixed Cost per House	\$ 29,424.00	\$ 6,350.00

Table 5: Yearly Costs of Private vs. Public Water

	Public Water	Private Well, No Treatment
Consumption Cost per year		
2007	\$ 454.56	\$ 429.77
2008	\$ 493.04	\$ 444.37
2009	\$ 535.26	\$ 459.55

Table 6: Per thousand gallon cost of water, 2007

	Public Water	Private Well, No Treatment
2007 Cost of Water	\$ 454.56	\$ 429.77
Average Gallons per hh per day	250	250
Days in Year	365	365
Gallons per Year	91250	91250
Cost/1000 gal	\$ 4.98	\$ 4.71

Table 7: Value of groundwater per thousand gallons in 2008 and 2009

	Public Water		Private Well, No Treatment	
2008 Cost of Water	\$	493.04	\$	444.37
Average Gallons per hh per day		250		250
Days in Year		365		365
Gallons per Year		91250		91250
Cost/1000 gal	\$	5.40	\$	4.87
2008 Cost of Water	\$	535.26	\$	459.55
Average Gallons per hh per day		250		250
Days in Year		365		365
Gallons per Year		91250		91250
Cost/1000 gal	\$	5.87	\$	5.04

B. Figures

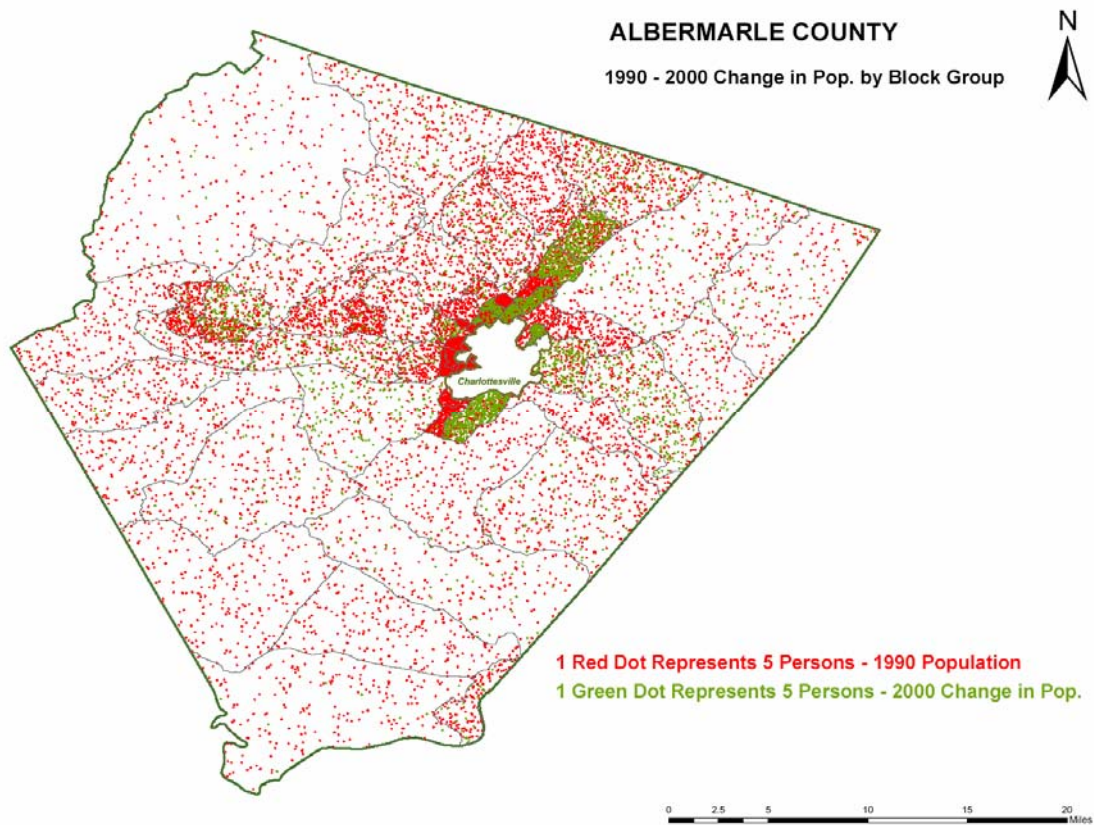


Figure 4: 1990 - 2000 Change in Population created by the Author with mapping assistance provided by Southside Planning District Commission

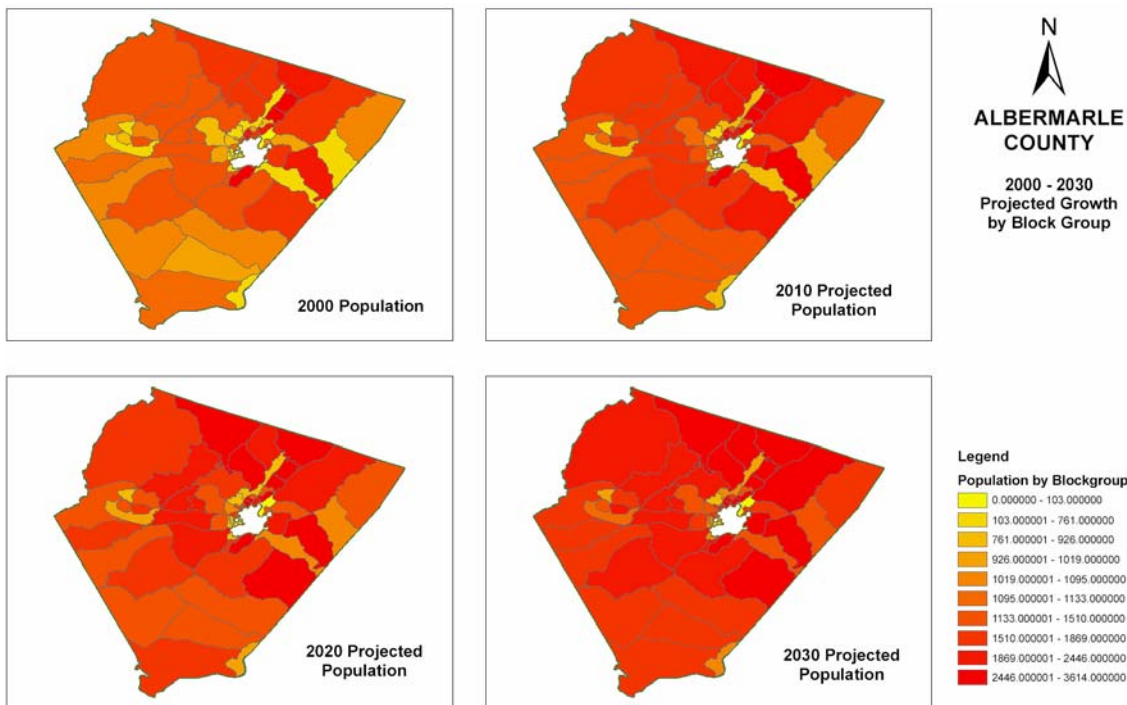


Figure 5: Projected Population Maps for Albemarle County created by the Author with mapping assistance provided by Southside Planning District Commission

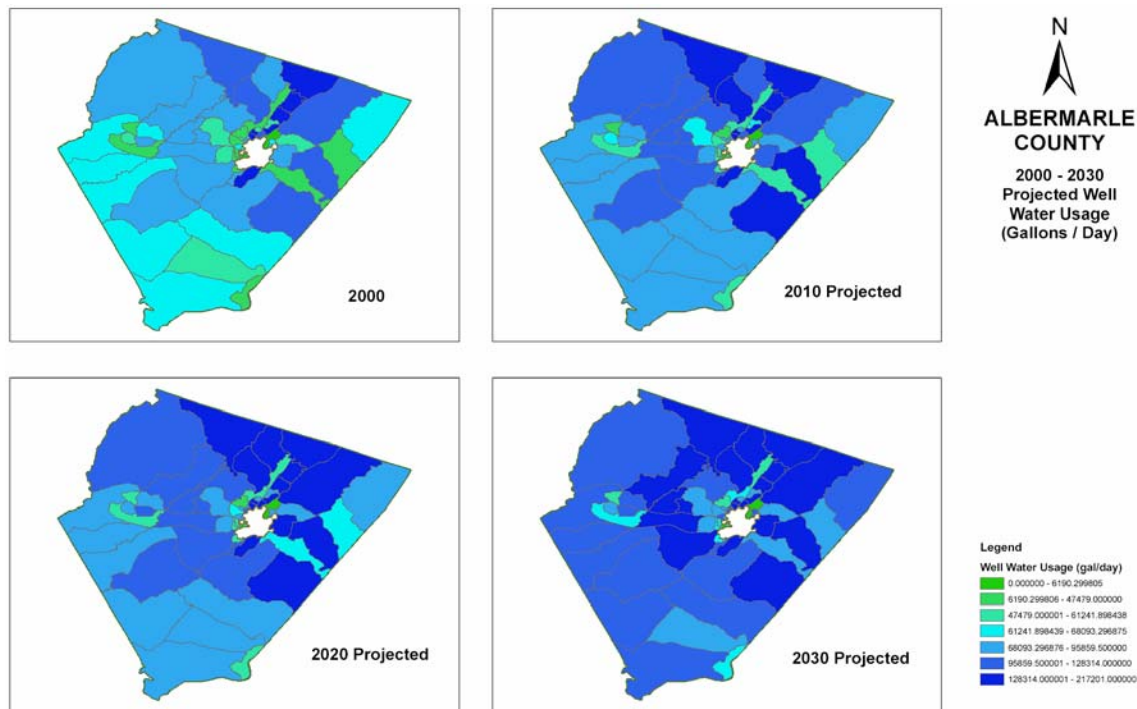


Figure 6: Projected Water Usage Rate Maps created by the Author with mapping assistance provided by Southside Planning District Commission