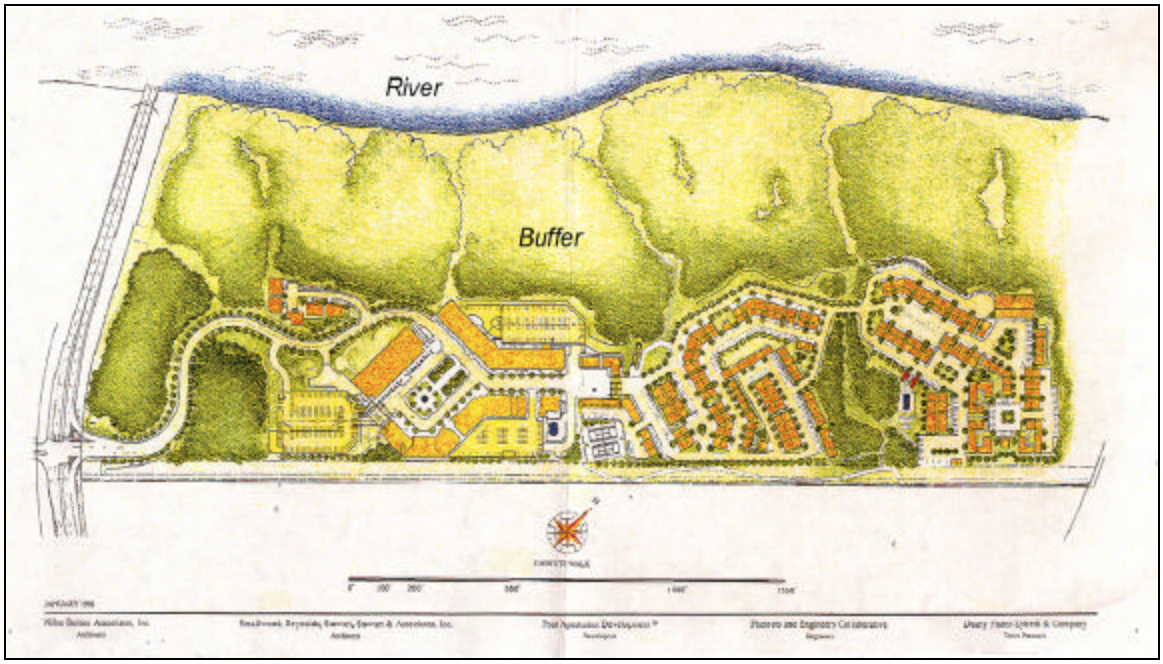
Case Study of Riverside, GA: Comprehensive Report of the Impact of Urban Design on Water Resources



December 2003

Joseph MacDonald[1] and Michael Holmes[2]

Department of City and Regional Planning, University of North Carolina at Chapel Hill[1]
College of Design, NC State University[2]

Project funded by: Water Resources Research Institute, The University of North Carolina

RIVERSIDE (ATLANTA, GEORGIA)

INTRODUCTION

Riverside is an 85-acre New Urban development in the City of Atlanta, Georgia, one of the largest and most rapidly growing metropolitan areas in the United States. Rapid growth had lowered air quality in Atlanta due to a rise in vehicle emissions resulting from sprawl and traffic congestion. Federal policy to improve air quality through reductions in funding for new highway construction prompted the developer to strive for a compact, mixed-use, urban form on the Riverside site. Local environmental groups wanted the project to be successful as a counter to sprawl, but they were also concerned about the impact of such a high-intensity development on the nearby Chattahoochee River.

Three issues define how Riverside impacted the Chattahoochee River. These issues derive from two land use policies used to guide development, and the implementation of those policies through site design.

The first issue is how Riverside's riverfront was protected by the Atlanta Regional Commission (ARC) through the State of Georgia's 1973 Metropolitan River Protection Act. Although the Riverside property fronted the Chattahoochee River, the ARC protected the portion of the site within 500 feet of the water's edge from human disturbance. The developers of Riverside also preserved land near the entrance of the site, due to challenging topography and the 100-year floodplain, and at the rear, due to close proximity of an interstate freeway. The remainder of the site was developed in accordance with ARC regulations based on land vulnerability and development impact.

The second issue is how the location and topography of the site limited opportunities for alternative forms of transportation, making Riverside more automobile-dependent and increasing the risk of pollution to the Chattahoochee River from street and parking lot runoff. Reliance on the private automobile contradicts the objective of lower vehicle emissions mandated by the United States Environmental Protection Agency (EPA) for the Atlanta region. Violation of the 1972 Clean Air Act by the Atlanta region compelled EPA to impose federal sanctions against highway construction in Atlanta in 1994. The developed portion of the site essentially functions as one giant cul-de-sac. No roads, sidewalks, or bike paths connect Riverside to neighboring developments. Furthermore, the site is restricted to private access by a guarded gate. Finally, there is no available public transportation to the site.

The third issue is how ARC's land use regulations encouraged a creative approach to stormwater management. The ARC wanted the developers to mitigate some of the impact of Riverside's reliance on the private automobile. Steep terrain, a rugged surface, and extremely close proximity of the development to the Chattahoochee River proved noteworthy challenges. However, through extensive negotiations with ARC representatives, the stormwater designers for the site crafted some very innovative best management practices (BMPs) to satisfy ARC's request.

SETTING

Riverside was developed on one of the last pristine parcels of land in the City of Atlanta. The site is located on the banks of the Chattahoochee River (see Figure 1). The terrain is dramatic, with the steepest slopes from 25% to 40% from the river's edge to the ridges on which Riverside was built. This area along the Chattahoochee River is known as "The Palisades" and is one of the most environmentally and topographically challenging landscapes for developers.[1]

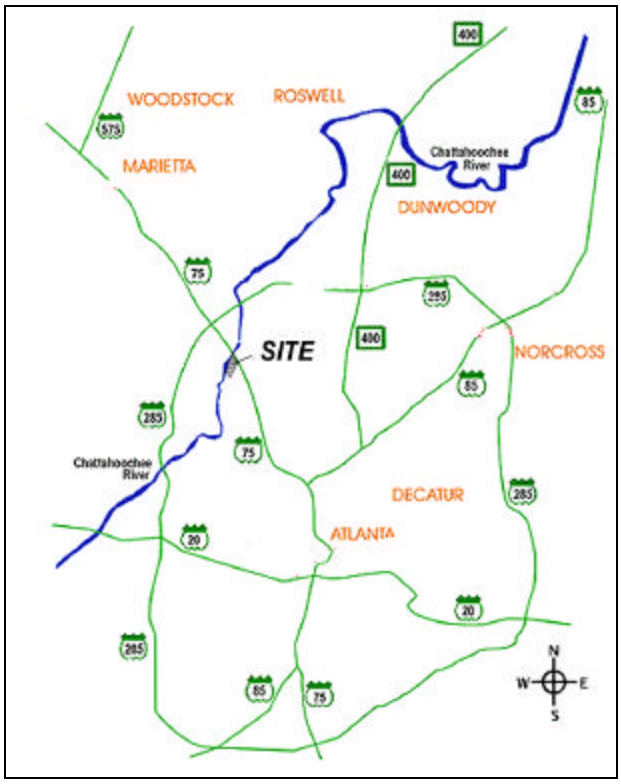


Figure 1. Riverside Site Location

The Atlanta Metropolitan Statistical Area (MSA) has experienced substantial growth during the last 20 years (see Table 1 below), particularly compared to the growth of the rest of the state. Between 1980 and 2000, the Atlanta MSA grew by 84%. Subtracting the Atlanta MSA population from the state's population reveals that the rest of Georgia grew by only 26% between 1980 and 2000. As a result, more than half of all Georgia residents (50.2%) lived within the Atlanta MSA by 2000.

TABLE 1. Population and Population Growth of Political Jurisdictions that Contain Riverside

SPATIAL UNIT	POPULATION			POP CHANGE (%)
	1980	1990	2000	1980-2000
CITY	425,022	393,929	416,474	-2.0
COUNTY	589,904	648,776	816,006	38.3
METRO AREA	2,233,324	2,959,500	4,112,198	84.1
STATE	5,463,105	6,478,149	8,186,453	49.8

Source: U.S. Census Bureau

Such strong population growth and its associated sprawling development created poor air quality by the late 1980s. Between 1987 and 1989, the Environmental Protection Agency (EPA) measured abnormally high ozone levels at several different sites around the Atlanta region. The results prompted the EPA to declare 13 counties in the 20-county Atlanta MSA in violation, or non-attainment, of the 1972 Clean Air Act. The EPA determined that these 13 counties collaborate to produce a plan in 1994 for attaining federal ozone standards by 1999 (Georgia Department of Natural Resources 2001). The non-attainment counties were unable to do so, and EPA imposed sanctions against federal funding for new highways in the non-attainment area until ozone standards were met.

One of the results of EPA's actions toward Atlanta was a shift in location focus among the development community. Since the federal government would no longer subsidize new or widened roads in most of the Atlanta MSA, developers turned back toward the City of Atlanta and its inner-ring suburbs where roads were already established. As a result of infill building, the City of Atlanta's population grew by 5.7% in the 1990s after declining by 7.3% during the 1980s. The central county of the region, Fulton, grew 26% in the 1990's compared to just 10% in the 1980s (see Table 1). Thus, the 1990's saw a shift in population back toward the City of Atlanta due to an increase in development within the core of the region. Pressure to build in the city was on the rise.

SITE DESIGN FEATURES

The majority of Riverside was been protected from human disturbance. A conservation buffer along the Chattahoochee River (see Figure 2) extends 500 feet inland from the water and safeguards 36 acres. The developer protected additional areas to avoid steep slopes, the 100-year floodplain, and close proximity of Interstate Highway 75. The undisturbed area remains heavily wooded with rocky outcrops and slopes approaching 40%. The disturbed area retains very little natural vegetation. The developer has lavished the areas around the buildings, roads, sidewalks, and parking decks with extensive landscaping (see Figure 3).

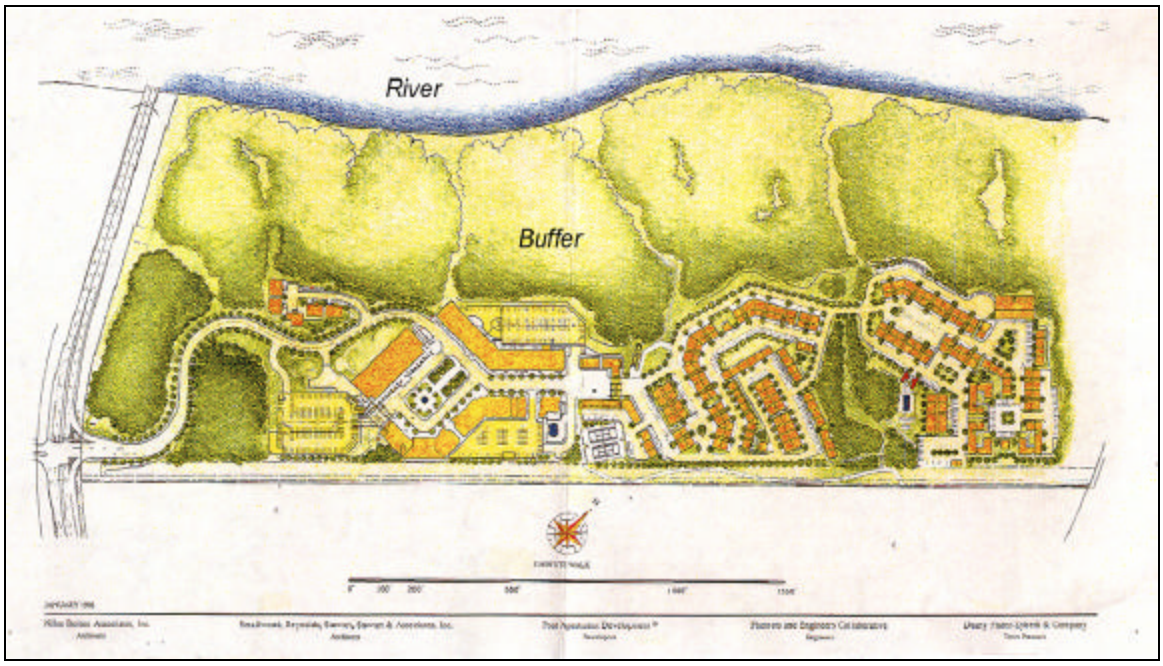


Figure 2. Riverside Master Plan

Figure 3. Landscaped Entrance to Riverside

Riverside is divided into two parts: a public town square with office, retail, and residential uses and a private (gated) residential component of low-rise apartment buildings and recreational facilities (see Figure 4). Both portions of the development include substantial parking, mostly in the form of decks. There are a total of 527 residential units, 521 of them rental apartments. Six condominium townhouses are between the town square and the entrance. The town square (see Figure 5) contains 225,000 square feet of office space, including the nine-story headquarters of the

development company, 25,000 square feet of retail space, and a small number of apartments. The private section includes most of the rental apartments, tennis courts, and a community garden.

Figure 4. Public Street Terminates at Gatehouse

Figure 5. Riverside Town Square

Riverside has experienced considerable market success. The developer has achieved nearly 100% occupancy rate of the 527 apartments and sold all six townhouses. Studio apartments rent for $863; 1-bedroom apartments rent for $1,148 to $1,538; 2-bedroom apartments rent for $1,675 to $2,755; and 3-bedroom apartments rent for $2,550 to $4,015. Base price for a townhouse was $1,000,000.

LAND USE POLICY FRAMEWORK

Two key land use policies influenced how Riverside impacted the Chattahoochee River: 1) The 1973 State of Georgia Metropolitan River Protection Act (MRPA); and 2) The 1994 federal highway funding sanctions imposed against 13 counties in the Atlanta MSA by EPA because of violation of the 1972 Clean Air Act standards for ozone.

The first land use policy that affected the impact of Riverside on the Chattahoochee River was the Metropolitan River Protection Act (MRPA). The site that was to become Riverside was under the planning guidance of the Atlanta Regional Commission (ARC) as early as 1971, when the ARC was formed and charged with the responsibility to conduct Area Plan Reviews for significant development projects in the Atlanta area. Growing environmental concern for the river in the late 1960's and early 1970's led to the Chattahoochee Corridor Study in 1972, a comprehensive analysis and scientific assessment of the different sections of the Chattahoochee River which faced the greatest threat from development (see Figure 6).

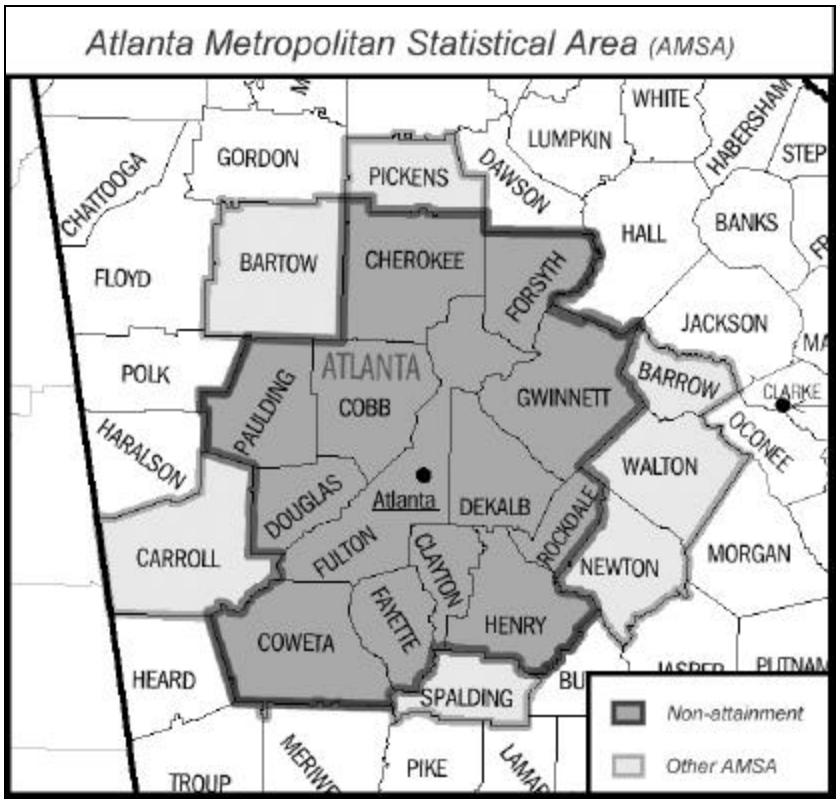


Figure 6. Thirteen Non-Attainment Counties of Atlanta Metropolitan Statistical Area (AMSA)

The Georgia State Legislature passed the MRPA based on the results of the Corridor Study. Since the act was passed as State Code, the ARC was granted the police power of the state to be the enforcement authority for development in the Chattahoochee Corridor. Specifically, the act translated into the Chattahoochee Corridor Plan, which applied to a zone that extended 1,000 feet from the riverbank on each side. The first 500 feet from the riverbank were designated a conservation buffer, where human disturbance was prohibited, while the zone 500-1,000 feet from the riverbank was designated developable with stipulations. The stipulations for this zone were derived from the land vulnerability and land use impact analyses previously conducted in the Chattahoochee Corridor Study.

The ARC implemented a land vulnerability and land use impact analysis in the Chattahoochee Corridor to ensure future development supported the two most important goals identified in the study: 1) water quality preservation; and 2) location and design of land uses in such a way as to minimize the adverse impact of urban development on the river and adjacent lands (Atlanta Regional Commission 1972). The land vulnerability analysis assessed vegetation, hydrology, soils, slope, aspect, and geology. ARC rated areas of the landscape based on vulnerability to development across all six categories, then added the scores from each category to obtain a composite score for land vulnerability. A similar approach was used to determine the impact of various uses on the landscape. Scores were assigned based on the type and intensity of proposed land use, with 0 being the lowest impact and 100 being the greatest impact. The land vulnerability and land use impact scores formed a pair of "grades" for the amount of land disturbance and imperviousness allowed for each area. Grades ranged from A to F for both maximum disturbance (A=90%; F=10%) and maximum imperviousness (A=75%; F=2%) permitted in a particular location.

To develop a site with MRPA restrictions, a designer must consider the site for both its land vulnerability and the impact of the intended land use. If the desired project is not compatible with the site based on the assessment of the ARC, then the development cannot be implemented. However, the developer may limit disturbance and/or imperviousness in more sensitive areas in return for more intense development in other areas. This process of "trading" use and intensity to achieve the desired development pattern is only possible through the ARC.[2]

The second land use policy that affected the impact of Riverside on the Chattahoochee River was the 1972 Clean Air Act. The Clean Air Act established National Ambient Air Quality Standards (NAAQS) for a number of different pollutants, including ozone.[3] The EPA made ozone measurements across the United States to determine if there were violations of NAAQS. Their findings prompted five classifications of ozone "non-attainment" in the 1990 Clean Air Act Amendments (CAAA).[4] The five possible non-attainment classifications were: Marginal, Moderate, Serious, Severe, and Extreme. Atlanta was labeled "Serious Non-Attainment" by EPA and required to submit a State Implementation Plan (SIP) by November 1992 to show how it would change regional emissions policy to meet federal air quality standards. The Georgia Environment Protection Division (EPD) failed to meet this deadline. On January 15, 1993, the EPA

sent a "finding" letter to the EPD, starting an 18-month "sanction clock" for the Atlanta non-attainment area. The sanction clock meant that if the EPD did not submit an appropriate revision plan by July 15, 1994, the EPA had the authority to impose sanctions on the region.

The Georgia EPD was unable to develop a plan by the 1994 deadline to bring the Atlanta area to attainment by 1999, so the EPA applied both of its sanctions against the 13 non-attainment counties in the Atlanta MSA (see Figure 7). One sanction focused on emission reduction from stationary sources, while the other sanction restricted federal funding for highway projects as a means to reduce automobile emissions. Since Atlanta had relatively more emissions from mobile sources than stationary sources compared to other non-attainment regions (Georgia Department of Natural Resources 2001), the sanction restricting federal highway funding served as catalyst for anti-sprawl development in the Atlanta region. Many in the development community, used to riding the wave of strong suburban growth and expansion, were forced to consider the reality put forth by the Georgia Department of Natural Resources (2001, p. A-5):

> Population and emission levels that previously led to violations of the ozone standard…in the MSA core, will continue to contribute to that problem and eventually result in violations in those non-MSA counties if present development and growth patterns continue unchanged.

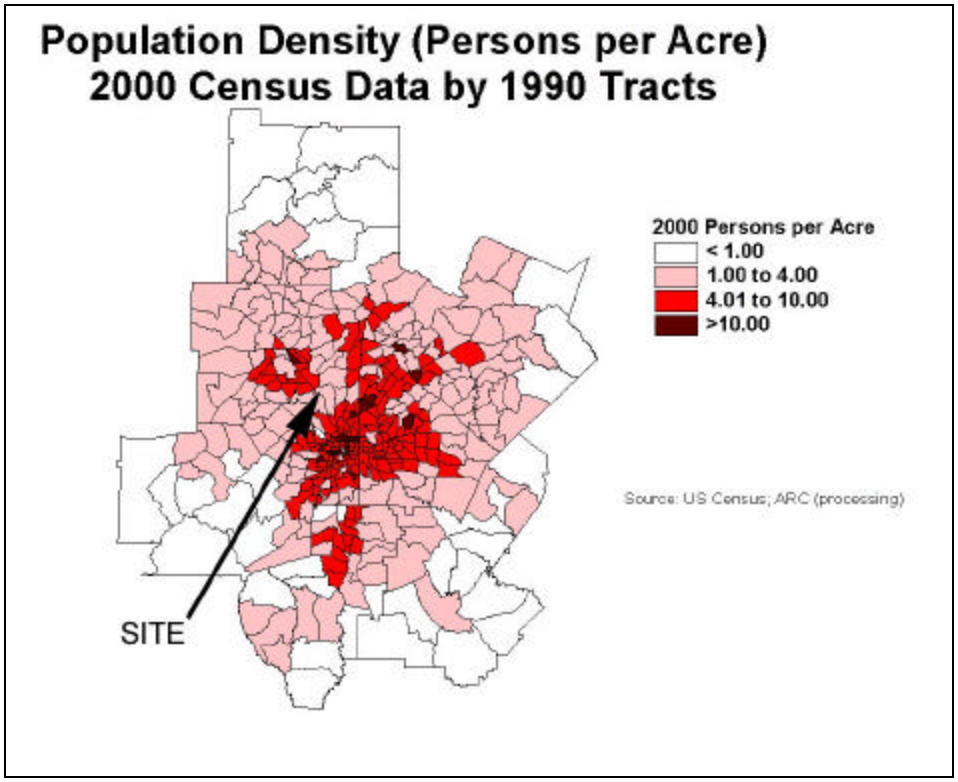


Figure 7. Location of Riverside with Respect to Spatial Pattern of Atlanta Population Density

The EPA sanctions shifted some of Atlanta's growth momentum back toward the city and its inner suburbs. Leaders in the building and development industry felt pressure to turn back toward less developed areas of the central core of the Atlanta MSA for new development opportunities. The areas near the Riverside site in particular were much less densely developed than surrounding areas (see Figure 8). Many of these sites, formerly by-passed for greener pastures, now had the full attention of a development community striving to create more livable, sustainable, urban neighborhoods.

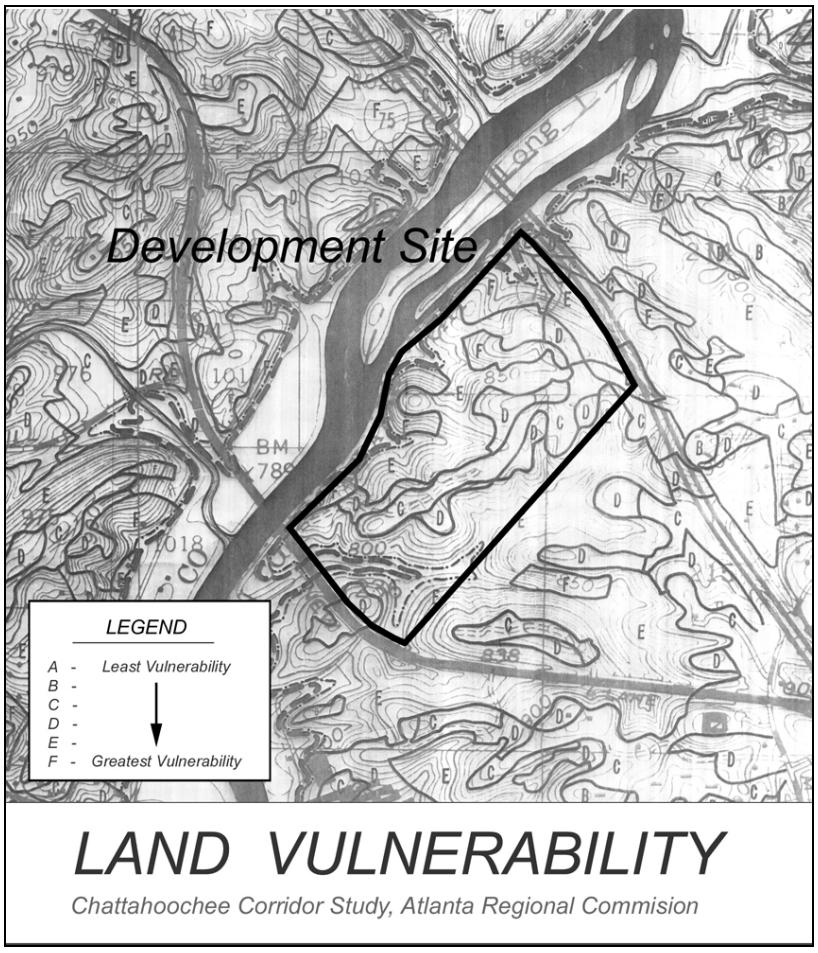


Figure 8. Riverside Site Vulnerability

SITE DESIGN

The land use policies created by the ARC and the EPA translated to three site design issues that defined Riverside's impact on the Chattahoochee River. First, the area of undisturbed land created by the ARC and the developer protected most of the site from development impact. Second, the withdrawal of federal highway funds from the Atlanta area pressured the developer of Riverside to build intensely in a small, difficult envelope. However, the challenging topography of the site and restricted access to neighboring properties forced a circulation system that increased automobile dependence. Excessive use of cars and lack of alternative transportation meant a greater risk of pollution from automobile effluent. Third, ARC's desire to protect the Chattahoochee River through its

land vulnerability and development impact analysis motivated Riverside's stormwater designers to innovate various BMPs to clean and control runoff. However, they struggled to maximize BMP effectiveness due to rough terrain and close proximity to the river.

Zone of Non-Disturbance

Riverside's development firm purchased the property more than two decades after the MRPA was approved. The previous owners had purchased a much larger piece that extended further east from the river. However, they only developed the eastern half. Eventually they split the property and sold the western half to the Riverside developers. Thus, the Riverside developers purchased the property with full knowledge of the conservation buffer and the ARC authority to regulate land use (see Figure 9). The developable portion of the western half of the original site was reduced further by 36 acres dedicated to the conservation buffer, leaving only 49 acres for development (see Figure 10).

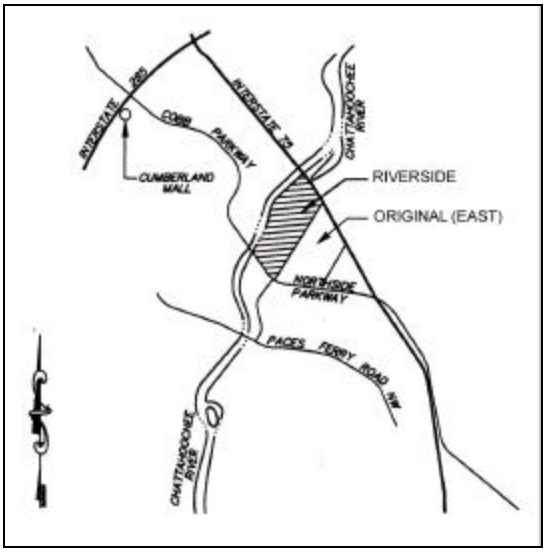


Figure 9. Riverside: West Half of the Original Parcel

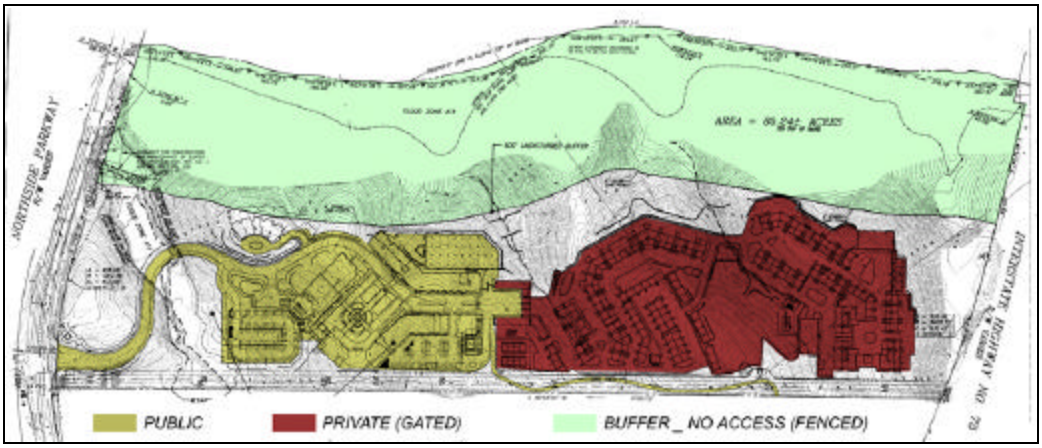


Figure 10. Riverside: Buffer and Development (Public and Private)

At the time of the Riverside purchase, the developers had no special vision for the property. The site was challenging due to topography and natural features and was one of the last undeveloped parcels of land in the City of Atlanta. With the impetus for infill created by EPA's sanctions, the developers decided that this property was too special to repeat the same pattern of apartment complex upon which they had solidified their reputation. The development corporation really wanted a home office in Atlanta; they wanted a timely, state of the art project that would set a standard for new development in a city that was experiencing new growth. The development manager for the site attended a lecture on New Urbanism. While at the lecture, the manager had a self-described "epiphany" about New Urbanism as the vision they sought. The development company then approached one of the most prestigious New Urban design firms in the United States, the "gurus of mixed-use" (Hassinger 1999), to create an antidote to sprawl and air pollution on just 49 acres. The developers for this site met with the design firm and arranged for a community charrette in Atlanta so that more could learn about the possibility of New Urbanism on the site. The developers and constituents who heard the presentation called it a "breath of fresh air" compared to past proposals for suburban-style apartment development in the city.

However, the manifestation of the New Urban concept on a site as poorly accessible and topographically challenging as Riverside proved extremely difficult. Thus, the developers decided the development would only have one entrance and there would be no disturbance of the floodplain or steep slopes near the entrance of the site. Furthermore, the developer wanted to keep the project upscale and thus insulate the residents of the private portion from the noise and unsightliness of traffic on Interstate Highway 75. Thus, within the developable portion of the site, 13 acres were protected from disturbance for these various reasons. The development envelope of the site only included 36 of the original 85 acres, leaving 49 acres (58% total site area) protected from disturbance (see Figure 11).

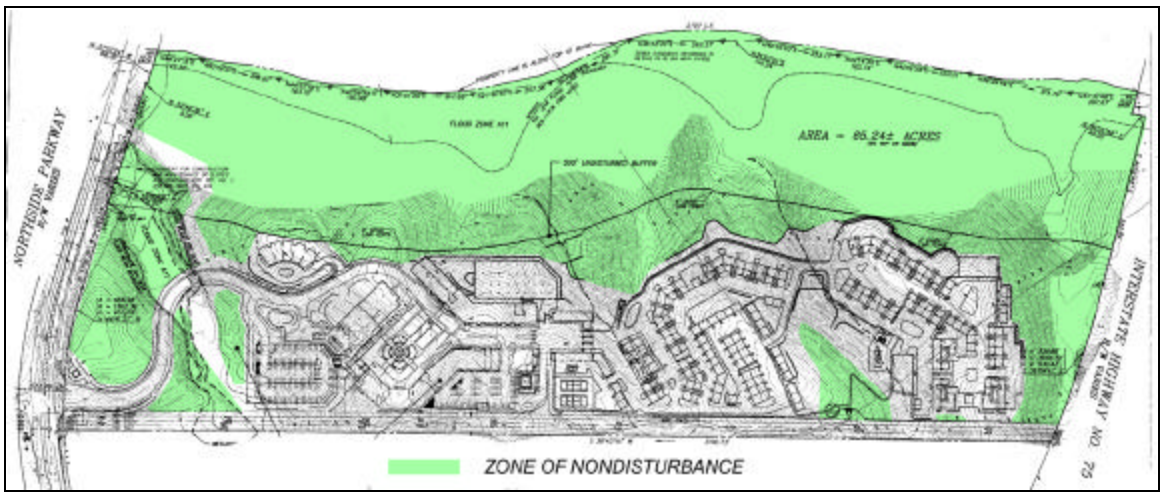


Figure 11. Riverside: Zone of Non-Disturbance

Automobile Dependence and Pavement Pollution

According to an engineer who helped design Riverside, it was very difficult to incorporate a well-connected street network within the site's development envelope for a variety of reasons, the most important being lack of access to other sites. Riverside is long and narrow. To the west is a utility easement and the developed half of the original parcel. The previous owners made no provision to connect the properties once they had split the original parcel and sold the western portion to the Riverside developers. To the north is Interstate Highway 75. To the east is the ARC buffer. To the south is Northside Parkway, the only feasible connection between Riverside and the rest of Atlanta (see Figure 10).

Another inhibitor for street connectivity is site topography. Riverside is not characterized by smooth terrain. Rather, the development sits on a series of valleys and ridges that orient themselves at nearly right angles to the Chattahoochee River. The configuration of these valleys and ridges, and the steep slopes between them, discouraged multiple road crossings. Rather, a single road connected all nodes of development.

Finally, the developer's penchant for tradition discouraged connectivity. The developer had constructed numerous apartment complexes all over the Southeast United States. These apartment complexes had always been very upscale. A signature feature of the developments was a guarded gate to restrict access to non-residents. The development company did not yield this practice in Riverside. The "back" half of the development is restricted to residents only. A grid street network would have compromised the developer's desired restrictions on access.

The dependence of Riverside residents and employees on private automobiles does not bode well for the Chattahoochee River. Riverside is a community only accessible by car - essentially a large cul-de-sac next to the river (see Figure 13). Although the developer reduced imperviousness through the use of parking decks instead of surface lots and only disturbed 42% of the total site, excessive automobile use means excess exhaust, oils, and other polluting effluents that may be washed into the Chattahoochee River watershed. Furthermore, the developer's portrayal of Riverside as a model for future development sends the wrong message by continuing the car culture the developer was trying to avoid because of EPA sanctions.

Atlanta planners criticized Riverside developers for deliberately limiting alternative transportation options access based on fears about security. Developers shied away from expanding the site hike/bike trail that could have possibly provided more access to other areas of the city (see Figure 12). Planners also cited the developers' fears regarding public transit, stating developers did not want to encourage possible undesirables from using transit to reach Riverside and its enclave of upscale shops and private apartment homes. In their interviews, the planners reasoned that the developers intended the "public" town square of Riverside, and its associated retail space, for the residents and employees of Riverside only. Others from outside the confines of the development were not encouraged to enter.

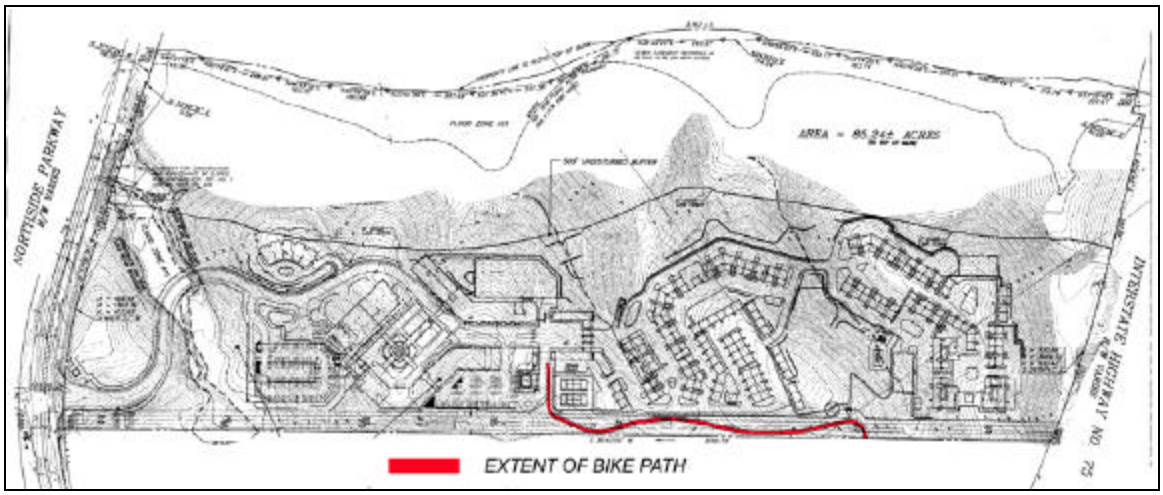


Figure 12. Riverside Bike Path

Stormwater Best Management

The long, narrow dimensions of the property ensured that nearly all of the developable portion of the site would be subject to ARC's vulnerability/use impact grading system. Thus, the development design for Riverside evolved through a series of negotiations between the developer's stormwater engineer and the ARC review committee. These negotiations involved significant rearranging of various elements of the plan over time as the stormwater engineer worked to satisfy the ARC's place-based requirements for disturbance and imperviousness through New Urban design. The result was a series of innovative stormwater BMPs that helped mitigate the effect of Riverside and its auto-dependency on the Chattahoochee River.

However, the New Urban design firm hired by the developer had never before dealt with topography like that of the Riverside site. Almost from the beginning, there was direct confrontation between the design firm's aspirations to produce a New Urban community and the severe restrictions on development by the ARC. It was the responsibility of the stormwater engineers to work within the parameters set by the ARC, in addition to the natural constraints of site topography (steep slopes, rock surfaces, and ridges).

Riverside is separated into three drainage basins served by four stormwater facilities (see Figure 13). Two of the facilities are located in parking decks. The other two facilities drain most of the developed portion of the site and nearly all the buffer along the river. The two ponds placed in the parking decks are called "vaults" (see Figure 14). These are for detention purposes, not water quality treatment. Water is filtered for major trash and the velocity reduced to allow large sediments to fall out. 2 splitter boxes (gateways between the vault and the landscaped areas outside the parking decks) act as the filters and velocity reducers. These boxes will hold the first flush (½ inch of rainfall in the first 24 hours). Water is then released into forebays (constructed wetlands with landscaping and rock weirs (i.e. check dams)) where there is some treatment of water quality. In the wetlands, water flows through vegetated pools and over rip-rap for filtration and treatment before it reaches the Chattahoochee River.

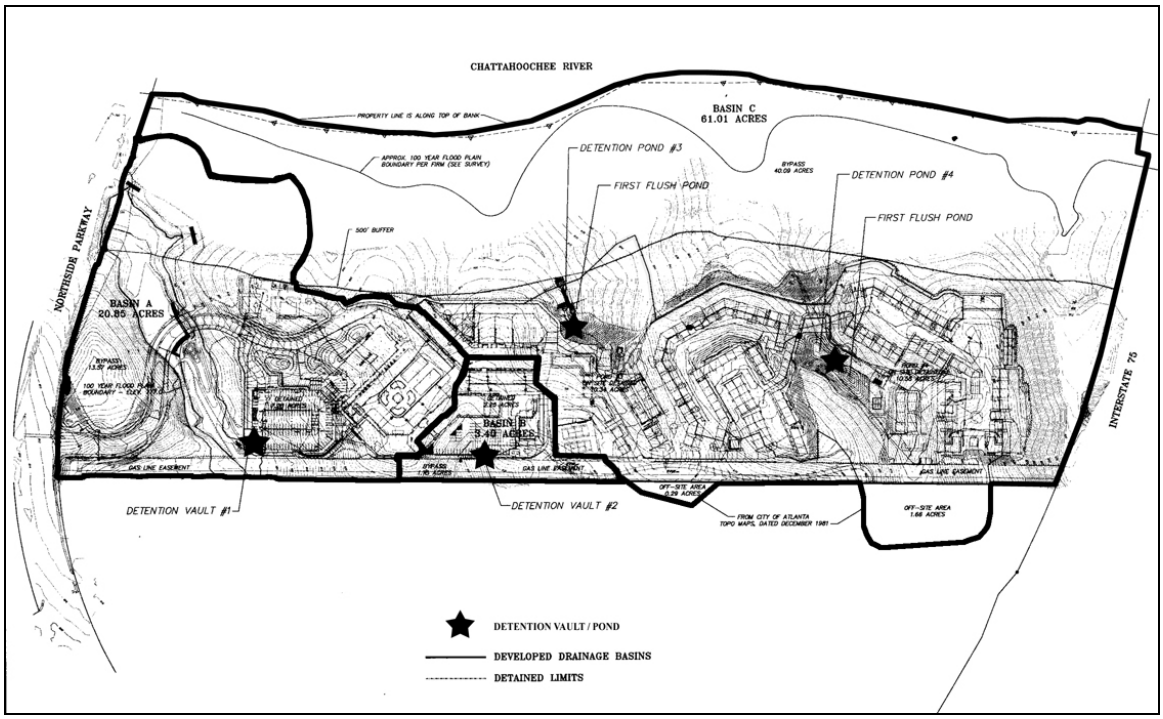


Figure 13. Riverside Stormwater Management Plan

Figure 14. Stormwater Detention Vault

The two open ponds, including one in the gated all-residential section, are really pond couplets (one pond controls runoff while the other pond cleans runoff; a splitter box keeps water in the first pond until cleaner water in the second pond is released). This method uses the concept of a "French drain," in which rocks, gravel, and vegetation treat

the first flush of water that enters the system. If rainfall is heavier than first flush levels, flow is released without treatment.

Springheads that surfaced on the site were also protected. These groundwater sources were kept piped under the surface until they were in the buffer. Piping protected the otherwise pure groundwater from surface contamination due to human development. Temporary sediment traps for erosion control were set up near the springheads to prevent any degradation to spring water quality from construction disturbance.

The location of Riverside and the intensity of the developed portion of the site tested the stormwater management system the designers created. Infiltration into the clay soils and blasted rock found at Riverside is very slow and runoff is high. The close proximity of development to a major body of water like the Chattahoochee River doesn't allow much opportunity for treatment. Still, the protection of more than half the site from disturbance and the use of sophisticated stormwater BMPs are testimony to the perseverance of both the ARC and the stormwater engineers to maximize protection of the Chattahoochee River.

CONCLUSIONS

The Metropolitan River Protection Act was a major policy decision in 1973 that showed the foresight and proactive planning attitude of a region. The MRPA, administered by the ARC, created a framework within which development could occur in a sustainable way. This framework was designed to ensure the protection of one of the region's most precious resources, the Chattahoochee River. The developers of Riverside came with good intentions to promote a new form of urbanism in a city beset by sprawl and poor air and water quality, but the site they selected for such an experiment posed challenging, seemingly insurmountable, difficulties. The challenge was met through innovative design practices and, for most of the site, not disturbing the land at all.

What Worked?

Riverside developed within a pre-existing land use policy framework that required a 500-foot buffer between development and the Chattahoochee River, and a detailed regulatory framework that matched development impact with land vulnerability. This framework insured protection of a 2/3 mile stretch of pristine ecological riverscape known as "The Palisades." A further strength of the neighborhood is that the developers worked within their narrow envelope to create a compact, mixed-use community within the central city. Besides protecting an additional 13 acres to achieve 58% non-disturbance on the site, Riverside captured growth in the city that may otherwise have contributed to further sprawl in Atlanta's suburbs. Finally, the designers of the site were able to mitigate the effect of development on a sensitive landscape through the use of innovative stormwater detention and treatment facilities. This system both controlled the flow of surface runoff into the Chattahoochee River and kept the river cleaner through constructed wetlands, French drains, and protected springs.

What Did Not Work?

Despite the developer's push to accommodate growth inside the City of Atlanta, this is one of the most environmentally sensitive sites in the entire region. The challenge of the steep topography, rocky outcrops, and clay soils made such a project difficult to implement. The close proximity of the building site to the Chattahoochee River allows very little opportunity for stormwater treatment and runoff mitigation. Furthermore, this site has neither good access, nor good circulation, as a significant portion of the development is gated and inaccessible to all non-residents. The absence of public transit renders all residents and employers automobile-dependent. Thus, the site actually does the opposite of what it was originally intended to do: reduce surface ozone through lower vehicle emissions.

What Did Riverside Teach Us?

The ARC wisely protected the Chattahoochee River from projects such as Riverside long before growth pressures had reached the critical stage they are at today. Though the developers of Riverside deserve credit for working within the framework established by the ARC and trying to experiment with more traditional neighborhood development in the central city, this was a difficult site to do so. Too many site constraints made for a problematic design agenda. The national prominence of the developer and the New Urban site designers, extremely diligent stormwater designers, and a dedicated ARC staff met the numerous challenges of Riverside, mostly with some level of success. The result is a good project that reasonably adheres to the fundamental guidelines of New Urbanism, while still incorporating ingenuity in watershed protection.

REFERENCES

Hassinger, M. March 5, 1999. Williams Calls Riverside a "Living Laboratory," *Atlanta Business Chronicle*, Atlanta, GA: American City Business Journals, Inc. Retrieved July 25, 2002 from http://www.bizjournals.com/atlanta/stories/1999/03/08/focus32.html).

Atlanta Regional Commission. July 1, 1972. Chattahoochee Corridor Study. Atlanta, GA: (publisher same as author).

Georgia Department of Natural Resources. July 17, 2001. Georgia's State Implementation Plan for the Atlanta Ozone Non-attainment Area: Executive Summary. Atlanta, GA: Georgia Department of Natural Resources, Environmental Protection Division, Air Quality Branch. Retrieved July 8, 2001 from http://www.state.ga.us/dnr/environ/plans_files/plans/airsipsum.pdf

Georgia Regional Transportation Authority. 2002 (update). Retrieved July 25, 2002 from http://www.grta.org and http://www.grta.org/nwcs/GRTA_Website/index2.htm.

McHarg, Ian. 1969. Design With Nature. Garden City, NY: Published for the American Museum of Natural History by the Natural History Press.

[1] The Palisades are the most dramatic area of the River Corridor. Steep slopes and ridges with many cliffs and rock outcroppings dominate. The River is very disturbed and fast flowing in this area, with shoals, rapids and white water evident throughout. There are very few outward vistas. Vegetation is generally thick with many climax species extant, especially on the north slopes (Atlanta Regional Commission, 1972).

[2] Though local jurisdictions initially had the power to override ARC authority, the Duluth Amendment to Georgia State Code in the 1980's curtailed the power of local jurisdictions in favor of greater power for the ARC. Thus, the ARC review of a project is the key forum for development intensity negotiations.

[3] Ozone is a highly reactive compound formed when nitrogen oxides and volatile organic compounds are emitted from automobile exhaust and other industrial and manufacturing operations, and then react with direct sunlight. Ozone pollution tends to be greatest during months when the weather is hot and sunny with little or no wind. These conditions are typical during the summer months in Atlanta.

[4] Any area of the United States that averaged more than one day per year during the three-year measurement period of a one-hour ozone concentration at 0.12 parts per million or greater was designated non-attainment