ESTIMATING RETURN FLOWS IN NORTH GEORGIA-A GIS BASED APPROACH

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Abstract. Water supplies in northern Georgia have become increasingly stressed due to rapid population growth and subsequent withdrawals for municipal and industrial (M&I) use. Because of the lack of sewerage infrastructure, much of this new growth will likely be served by decentralized wastewater systems. Due to many factors, including a lack of information regarding location, size, hydrogeologic condition, soils, distance to surface water, distance to groundwater, etc., only cursory assessments of the wastewater return flows and performance of these systems has been performed. Statewide water policy has consistently assumed that these returns are negligible. However, their actual contribution to a basin hydrologic budget remains a possibly open research question. A qualitative, conceptual approach is proposed which integrates the most significant hydrologic processes. A Geographic Information System (GIS) based water budget model is presented and applied to a small, watershed tributary to the Chattahoochee River. Recommendations are then presented for refining the analysis and applying it on a basin scale and evaluating conditions during critical periods.

BACKGROUND

Metropolitan Atlanta's growth has led to an increase in the amount of what has become known as consumptive use, i.e., the difference between water withdrawn and discharged to the same source. A concern over consumptive use has become a focal point in the ongoing water dispute between the states of Alabama, Georgia, and Florida. Consumptive uses typically include those attributable to evaporative losses, including M&I use, evaporative cooling, and agriculture. Within the upper Chattahoochee basin, consumptive uses are primarily from urban turf irrigation and decentralized wastewater management, which include both septic and Land Application Systems (LAS).

Within the water, wastewater, and watershed plans for the Metropolitan North Georgia Water Planning District (MNGWPD), several assumptions were made in conjunction with the Georgia Environmental Protection Division (EPD). These discussions centered on the then ongoing Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) compact negotiations. The negotiators had reached a tentative agreement that flows from decentralized systems such as LAS and septic systems were 100% consumptive for purposes of water supply allocation, focusing primarily on low flow periods. A key performance metric of the MNGWPD plans was the requirement to return 70% of water withdrawal back to the Chattahoochee Basin; based upon 2030 water supply withdrawals and wastewater discharges, interbasin transfers, and consumptive uses. The plans developed an estimate of septic systems based upon extrapolation of a relationship between sewerage and density to obtain a current inventory and a year 2030 projection (MNGWPD 2003a). At the conclusion of the District planning, several policy goals were recommended, including a comprehensive inventory of septic systems. Because of funding limitations, a comprehensive inventory was not completed; however, recently the MNGWPD completed a thorough survey of systems from its 16 counties (MNGWPD 2006).

Subsequent to the adoption of the Plans by the MNGWPD, two key events occurred:

- Both ACT and ACF compact negotiations failed to reach agreement by all parties.
- The Georgia legislature passed House Bill 237, the Comprehensive Statewide Water Management Planning Act, which requires adoption of a Comprehensive Statewide Water Plan (CSWP) by 2008.

The first major policy framework advanced in the preliminary development of the CSWP is the establishment of Consumptive Use Budgets (CUBs) based upon withdrawals, discharges, and consumptive uses that occur within a given subwatershed. These CUBs would establish a regionally specific framework for potential management of CUB. Septic systems remain a key part of the CUB discussion; the intent appears to discourage their use in areas with high CUB. It is not known at this time at what watershed scale this approach will be implemented. As it was presented recently, this policy does not appear to include the inputs from either storage or interbasin transfers. Interest remains high in this subject primarily due to the high cost and difficulty in providing sewerage infrastructure to outlying regions of metropolitan Atlanta. Decentralized systems remain the default wastewater management system in the absence of a collection system infrastructure. The concern regarding consumptive use is at least partially driven by the potentially large numbers of systems that may be constructed from now to 2030. A review of the hydrologic impacts related to decentralized systems follows.

HYDROLOGY OF DECENTRALIZED WASTEWATER SYSTEMS

Land application and septic systems both consist of a vegetative cover over permeable soils. In a LAS, water is applied through either spray or drip irrigation, and percolates into the soil, where it is available for uptake by the vegetation. Losses may occur due to direct evaporation from the spray and the surface, transpiration by vegetation. The irrigation rate is controlled to reduce the potential for surface runoff to occur. If the water is not consumed by vegetative uptake, it will eventually recharge the shallow ground water table and usually flow downgradient to a surface stream. Septic tank systems consist of a tank and a leach field (see Figure 1). The tank provides primary treatment of wastewater flows, which are then discharged to a leach field, at a depth that varies between 2-4 feet. The leach field provides additional treatment of the wastewater primarily through adsorption on the soil matrix. Depending upon the depth of the leach field, some of the water may be available for uptake and thus be lost to evapotranspiration. The bulk of the remaining water will follow gravity and recharge the surface water table. The presence of this steady source of water may cause a fluctuating "mound" to occur directly beneath the leach field. Depending upon the local hydrogeology, the water will then flow downgradient to a surface stream.

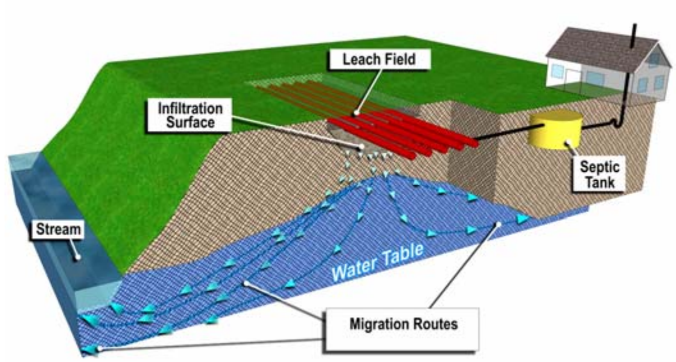

Figure 1: Septic Tank Concept Plan

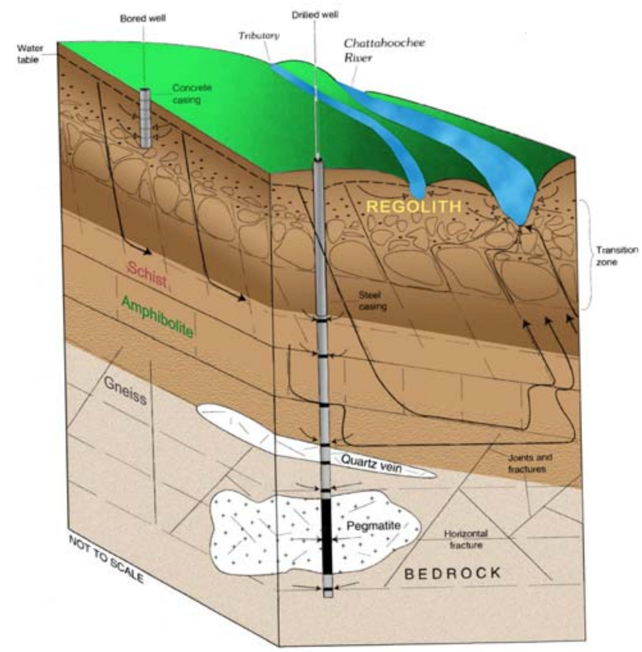

Figure 2: Typical Geologic Cross Section, Upper Chattahoochee Basin (USGS 1996)

In the Piedmont and Blue Ridge areas of North Georgia, groundwater exists in fractures and weathered zones of igneous and metamorphic bedrock (Figure 2). Groundwater in these zones is extremely heterogeneous and moves very slowly. Recharge can be assumed to be approximately equivalent to base flows on an overall average annual basis, with regional exceptions such as the Valley and Ridge region of northwest Georgia. It is thought that the time period for this process may be very long, and thus not be measurable. However, because of the delay or lag effect, this water may actually provide a small beneficial effect due to augmentation of base flows to small surface streams during dry periods. This could be an important benefit as it is well documented that base flows to tributaries of the Chattahoochee are declining due to urbanization (Calhoun et al 2003). Because of these potential benefits, it would appear that this area merits further analysis. In the following sections, a review of the work of others in the area of estimating recharge from decentralized systems is presented.

PREVIOUS WORK

Because of many factors, including a lack of information regarding location, size, hydrogeologic condition, soils, distance to surface water, distance to groundwater, etc., only cursory assessments of the wastewater return flows and performance of these systems has been performed to date. A review of this literature is provided in this section. Most of the published literature focuses upon surface and groundwater quality impacts from septic systems. We will first introduce the work performed within the state, and then proceed to other relevant work.

Radcliffe et al. (2006) performed preliminary modeling in Athens, Georgia for a typical year (1995) and found that 91% of the water discharged to septic systems went into the surficial groundwater table. Radcliffe et al. (2006) summarized the work of Cleveland (1990) and LAW (1998) which used a downstream gage near the headwaters of Pates Creek to evaluate an LAS system near Atlanta. Cleveland (1990) found that after the LAS system startup, annual discharge in the stream was 69% higher than its regional average. LAW (1998) was more specific, and found that 70% of the wastewater irrigated within the LAS reached the stream. In the development of the Watershed Plan, the MNGWPD developed a model HSPF (Hydrological Simulation Program – FORTRAN) for each 12-digit HUC (Hydrologic Unit Code, or watershed). This model is described in Hummel et al. (2003) and MNGWPD (2003b). In this model, septic tanks are included; however the focus is upon the loading provided to nearby streams rather than the water balance. Further work by the MNGWPD (2006) resulted in a comprehensive survey and additional work focused upon the water quality impacts and design of these systems.

Burns et al. (2005) monitored small flows within several residential catchments in upstate New York and computed lag times and base flows. The conclusions were that wetlands and septic systems exhibited significant contributions to base flows during dry periods, effectively mitigating base flow reductions from urbanization. Zarriello et al. (2002) conducted a watershed modeling study in the Ipswitch River Basin, Massachusetts, also found that septic systems would provide base flow augmentation of streamflow, and the combined effect of increased water supply withdrawals and zeroing out septic systems had a significant negative effect on streamflow unless wastewater returns were used for direct augmentation. The Institute for Food and Agricultural Sciences (IFAS 1987) found that in Gainesville, Florida septic systems could provide as much as 60% of the recharge to surficial groundwater on a lot level basis.

As can be seen from the published literature, it remains an open question what the extent of recharge occurs from these types of systems. Of course, this would vary significantly with the climate and hydrogeologic characteristics of the area. However, the literature does not appear to support the contention that decentralized systems are 100% consumptive.

GWINNETT COUNTY CASE STUDY

In order to better understand the processes involved, a small case study on a self contained watershed tributary to the Chattahoochee River was developed. For obvious reasons, the case study needed to be in an area served by septic systems. Based upon MNGWPD preliminary estimates, approximately 500,000 septic systems currently exist in the 16-county region. Gwinnett County has the most, at 88,600 (MNWPD 2006). The county has also instated several efforts aimed at 1) identifying failing septic systems, and 2) assisting in connecting households to centralized sewerage systems. Also, detailed GIS data were readily available.

We selected a self-contained watershed which drains to a small, short tributary and thence to the Chattahoochee Basin (see Figure 3). This small watershed was modeled with a qualitative, conceptual approach with the goal to integrate most significant hydrologic processes. We were assisted in this effort by the use of a software application, Mike-SHE and Mike-11 system, developed by the Danish Hydraulic Institute (DHI). This model is GIS-based, and integrates both grid-based and non grid-based geographic information. The model divides the catchment into small grid cells, each of which develops a water budget simulating fundamental hydrologic processes such as rainfall/runoff, infiltration, evapotranspiration, and shallow groundwater flow. Our results will be presented in graphical representation of a water budget, in which rainfall, evapotranspiration, irrigation, recharge, etc., are all presented in units of depth of water. The intent of our approach is trifold: to provide an illustration of the conceptual approach, to elucidate what the average annual return flow may be during dry periods, and to provide a potential framework for further work. A full scale analysis of this issue is necessary beyond the scope, however the overall goal is to provide a means of developing an approach to a potential sound science study funded at the state level.

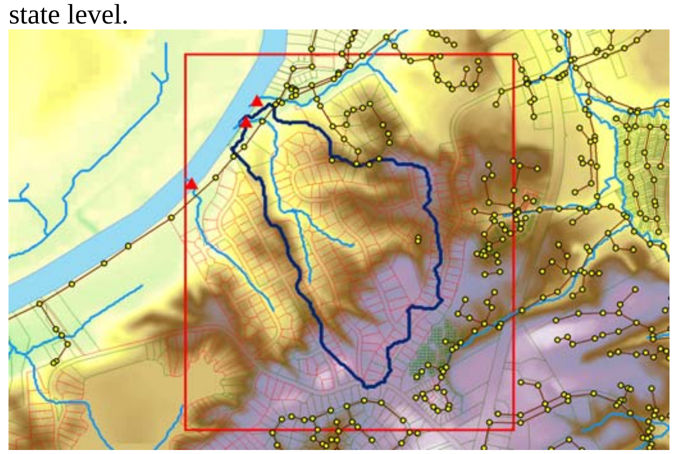

Figure 3: Case Study Conceptual Model

PROPOSED REGIONAL APPROACH

The analysis presented in the accompanying presentation could be extended regionally in the following ways:

1. In order to calibrate the microscale model direct measurements and tracer studies should be performed.
2. The analysis could be extended by developing several additional models of small areas within the Chattahoochee basin upstream of the Whitesburg gage. These can be spread out spatially to represent different cases (i.e., distance from stream, varying hydrogeology, etc.); however, they will be necessarily limited to areas that can provide detailed GIS coverage.
3. Scenarios can be developed which include with and without sewerage options.
4. Spatially aggregate the results into a regional hydrologic model. Future conditions analysis can be evaluated by using MNGWPD estimates of potential septic systems within the region.
5. An assessment of the effects on future allocation and water policy can be made to determine the relative advantage or disadvantage of inclusion of the returns (if any) into decisions.

We suggest that by developing a system of several detailed monitoring sites in small scale watersheds (with septic systems), a series of small, calibrated models can be developed. These can then be combined with larger scale models such as the MNGWPD HSPF model as a meta-model by calibrating it to the known conditions in the small watersheds.

SUMMARY AND CONCLUSIONS

State Policy is currently moving in the direction of restricting consumptive use through the establishment of CUBs. This policy could be used to limit the potential growth of decentralized systems, such as septic systems, which have become the default wastewater management system of north Georgia. This policy is intended to limit the expected impacts these systems may have on return flows. Little research has been done to date that integrates the effects of these systems; there is little scientific consensus on the issue itself. Therefore, quantifying these results may be a valid research area. A conceptual modeling approach is presented on small self contained watershed for illustrative purposes. We have also developed a potential method for extending these results to a regional scale.

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