Piedmont/Mountains Groundwater Resource Evaluation Study:

2004 – 2008 Strategy, Progress and Goals

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Groundwater Section

Walter T. Haven, P.G.
Richard E. Bolich, P.G.
Donald J. Geddes, Jr., P.G.
Charles G. Pippin, P.G.
Theodore R. Campbell

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Overview

The State-USGS Cooperative Piedmont/Mountains Groundwater Resource Evaluation Study is a component of a long term plan, funded by the legislature in SFY 2000-01 to assist in protecting the State's groundwater quality by characterizing Piedmont and Mountain area aquifers and defining areas of highly vulnerable groundwater. Knowledge of the shallow groundwater system where contaminants are leaked and spilled is necessary to establish appropriate levels of protection for State groundwater and surface water resources. This work is a critical protection activity that must be accomplished to develop a better understanding of the relationship between existing and future land uses and resultant changes in groundwater quality characteristics. Contamination of shallow groundwater can result in the movement of pollution into the deeper drinking water aquifers as well as degradation of the quality of surface waters.

The Division of Water Quality, Groundwater Section believes it is critical to its groundwater protection responsibility to complete the characterization of the State's groundwater system that is most vulnerable to contamination. This work began through the Section's efforts in the Basinwide Water Quality Management program, it continues with our work in the Piedmont/Mountains groundwater study, and additional work is proposed in the Coastal Plain in a plan that is under development. To protect State groundwater quality, the work must encompass all of the State critical groundwater use areas before these important resources become irrevocably contaminated.

Currently 2 to 20 percent of groundwater used for drinking water from private wells throughout the State can contain pesticides or nitrates at levels that may threaten human health. In Wake County alone, there are more than 370 groundwater contamination incidents and 60 wells impacted. In order to reduce these threats to the groundwater resources, it is necessary to not only control the contaminant sources but to also be able to understand how the contaminants move through the subsurface and into streams and the drinking water aquifers. With this understanding will come the knowledge to locate and construct drinking water wells to minimize the possibility of pollution and to reduce the possibility that citizens will be exposed to contaminated groundwater. The improved knowledge of groundwater vulnerability will also enable the Division to appropriately site waste management facilities to prevent the movement of contamination into drinking water wells and streams.

Research Station Development

The Piedmont/Mountain groundwater study involves the location of “Research Stations” within unique geologic settings, or type areas (Figure 1). Each station has clusters of shallow, intermediate, and deep monitoring wells, intersecting water within the saprolite, “transition zone”, and fractured rock, respectively. Staff hydrogeologists determine well location and depth, while installation is accomplished by the Groundwater Section’s certified drilling personnel. Site work involves geologic mapping of rock units, rock coring, groundwater flow/aquifer testing, groundwater sampling, well camera logging, and surface and borehole geophysics. On completion of site work, a report is
published that describes groundwater quality, vulnerability to pollution, and relationship
to land use and surface water resources.

The following sections delineate each Region’s current research activities as well as
upcoming projects to be implemented over the next several years.

**Raleigh Regional Office Research Stations**

*N.C. State University/Lake Wheeler*
*Raleigh, Wake County*

The major elements (well installation and testing) of the N.C. State University/Lake Wheeler hydrogeologic research station have been completed. On-going activities at this site include annual groundwater quality sampling to monitor any temporal changes in groundwater quality, educational outreach activities including site visits by various school groups, and training exercises conducted to benefit Groundwater Section personnel and other State and local government agencies. These on-going activities will be conducted throughout the next five years.

Activities planned at the Lake Wheeler research station include an assessment of nutrient concentrations in the fractured bedrock aquifer. Evidence gathered at the site as a result of our current research station activities indicates that groundwater containing anomalously high concentrations of nutrients is flowing underneath a drainage divide (Figure 2). This phenomenon has important implications for regulatory issues affecting Groundwater Section policies such as waste application boundaries and public health issues related to the risk from groundwater contamination to receptors. The Lake Wheeler research station presents a unique opportunity to investigate this phenomenon and improve the Groundwater Section’s permitted facility and pollution incident site management expertise.
Granite Bedrock/ Subdivision Site
Wake County

Work on the next groundwater research station planned for the Raleigh Region is currently underway. The new research station site is planned for an un-metamorphosed granitic bedrock geologic setting. Un-metamorphosed felsic igneous intrusions constitute an estimated 10% of the landmass of the N.C. piedmont and mountains. Utilizing contacts with Wake County government that were fostered through current Groundwater Section research, the planned granitic bedrock hydrogeologic research station site will be installed in a “typical” suburban housing development prior to its construction. Wells will be installed, sampled, and analyzed prior to the start of significant subdivision construction activities in order to monitor any changes in groundwater quality over time due to anthropogenic activities. This research station would be the first of its kind in the country, and will provide subjective data on impacts to groundwater quality and resulting from the changing land use.

Potential locations for a granite/subdivision site in Wake County are being determined, with negotiations for access underway. Timing is a crucial element to the success of this project due to the need for the research station wells to be installed and sampled prior to home construction. Monitoring well locations will be selected based on the developer’s preliminary lot layout, utilizing areas that will be in the NCDOT right of way to avoid disturbing residents. However, the Section is also prepared to install the granite research station on State owned land if we are unable to complete negotiations with a prospective cooperator.

Figure 2. Lake Wheeler Research Station groundwater quality. Although additional impurities were discovered, only those parameters exceeding 2L standards are shown.
One of the most pressing problems affecting groundwater quality in the Raleigh Regional Office is nutrient contamination from land application of wastewater residuals. The largest groundwater contaminant plume in North Carolina is believed to be the result of over-application of residuals at the City of Raleigh’s Neuse River Wastewater Treatment Plant (NRWTP). The treatment plant’s residuals are land applied in a granitic hydrogeologic environment, which the RRO’s pollution incident management data suggests is very vulnerable to contamination from surface spills. Groundwater contaminated with nitrates has migrated beyond the regulatory compliance boundaries and is discharging into the Neuse River, which has been designated as nutrient sensitive waters by the DWQ.

One of the proposed remedial actions for the contaminated groundwater at the NRWTP is to estimate the amount of nitrate that is entering the Neuse River system from groundwater discharge and to subtract this amount of nitrate from the existing NPDES outfall permit for the NRWTP. This action would then require a variance from the regulatory requirement for active treatment of groundwater contamination resulting from permitted activities.

The RRO Groundwater Section will propose that as a condition for supporting a variance from 2L rules at the NRWTP, a land application hydrogeologic research station would be established at the NRWTP to enable DWQ to provide data to answer the following questions:

- Are established agronomic rates for residuals application sufficiently protective of groundwater quality?
- What hydrogeologic factors have a significant effect on the fate and transport of nutrients at residuals application fields?
- Does nutrient contaminated groundwater have a significant impact on surface water quality?

**Additional Research**

The Raleigh Regional Office, Central Office, and North Carolina State University are investigating the presence and risk of radon-contaminated groundwater within Wake and Franklin counties. This project involves the geological mapping of water bearing faults and residential supply well sampling. Information from this study will be used to assess the potential health threat to North Carolina citizens.
Winston-Salem Regional Office Research Stations

*Upper Piedmont Research Station*
*Reidsville, Rockingham County*

The Upper Piedmont Research Station (UPRS) is located on properties owned and maintained by North Carolina State University, the North Carolina Department of Agriculture, and the Penn 4-H Educational Center. The URPS provides information on groundwater conditions that is representative of large portions of the Winston-Salem region and the Piedmont of North Carolina. Additionally, the site provides a unique opportunity to study groundwater flow in two distinct flow regimes, results of which have important implications for groundwater contaminant migration, groundwater permitting conditions, and well siting. The majority of investigative work has been completed at URPS, with a summary of three sampling events shown in Figure 3. Remaining work includes groundwater sampling, development of educational displays, data analysis, borehole packer testing, refinement of the site conceptual model, and publication of a site report.

![UPRS Groundwater](image)

**Figure 3.** Upper Piedmont Research Station groundwater quality. Although additional impurities were discovered, only those parameters exceeding 2L standards are shown.

A fourth semi-annual groundwater-sampling event is planned for late spring of this year, after which we will begin sampling on an annual basis. Annual sampling of all wells, or a representative selection of wells, will continue for approximately six additional years.

The UPRS site includes a visitor’s educational walking trail with explanatory displays of ecological and historical items from the area. We are developing a display to explain the geology and hydrogeology based on our current understanding of the site, and how these factors influenced development of the locally historic Chinqua-Penn Plantation. We will also provide educational materials and help the 4-H Center develop a groundwater curriculum as part of their environmental education program.
Data analysis of test and sample results has been an on-going effort during data collection. However, we now have enough information from numerous testing methods that we are able to perform final site characterization with a more comprehensive approach. These types of analyses will be important to help refine the site conceptual model and to develop the site report. A draft version of the site report should be available later this year.

Borehole packer testing is currently underway to help refine our understanding of the groundwater system by allowing us to perform hydraulic testing and groundwater sampling (including age-dating) of isolated zones within each deep well. These activities will provide insight into groundwater movement and residence time within the system, which will enhance our ability to make educated and scientifically defensible policy and guidance decisions for groundwater management issues.

North Carolina Zoological Park
Asheboro, Randolph County

The Winston-Salem Regional Office is currently negotiating to install the next hydrogeological research station on North Carolina Zoo property. This venture will provide an excellent opportunity to conduct exciting, interagency cooperative studies within DENR. We have located potential drilling sites that meet the needs of both agencies. Zoo personnel have indicated a strong desire to help move our project forward. This project would comprise the majority of Resource Evaluation Program work in the Winston-Salem Regional Office over the next five years.

The Zoo is located in felsic metavolcanic rocks of the Carolina Slate Belt, which comprises a large portion of North Carolina and other eastern states. Groundwater quality and quantity concerns in the Slate Belt, as expressed by regional Groundwater Section staff and county health departments, helped inspire the goals for this project. There are currently no other systematic groundwater resource studies being conducted in the Slate Belt, even though groundwater issues are numerous, complex and diverse in the large geographic area encompassed by this geologic setting. Research at this site could therefore have far-ranging implications at many levels of government, including municipal, county, state and federal groundwater resource management programs.

The hydrogeological research station at the Zoo will include an important educational component. The Zoo is in the initial planning stages of a large water resources display within the main area accessible to visitors. Our study will have direct input on the groundwater aspects of this display, which will have high profile educational value to the general public. The research station itself will also serve as a natural laboratory for Zoo personnel to educate school groups about their environment.
Tanglewood Park  
Winston-Salem, Forsyth County

Another hydrogeological research station is also being planned at the Tanglewood County Park in Winston-Salem. This project has support from the Park Manager, as it will be a helpful addition to their environmental education program. The site is underlain by mafic intrusive rocks, which do not constitute significant portions of North Carolina but which are similar to other rock types in the state that do cover large areas. We do not have any other existing or proposed study sites in this geologic setting. The Tanglewood property is bound on one side by the Yadkin River, so we will have an opportunity to study the interaction between groundwater and a large river that serves as a source of potable water for numerous communities. Groundwater issues in this setting are not fully understood, even though there are important implications for contamination and permitted waste discharges to cause negative impacts to both groundwater and surface water. A study of this type would also produce data that could be directly incorporated into on-going river basin studies and may also provide additional insight into groundwater/surface water interactions within a stream buffer zone.

Poultry Litter Disposal Study  
Wilkes and Surry Counties

The importance of the poultry industry to local economies in the North Carolina Piedmont has been steadily growing over the last few decades. There are potentially hundreds of farms presently located in Wilkes and Surry Counties alone, with numerous new facilities being constructed each year. The waste product (or litter) from the poultry houses (composed of bedding material, manure and uneaten feed) is typically disposed via a land application process that takes advantage of the litter’s nutrients to fertilize agricultural fields. This process needs to be monitored to understand and abate the potential, resulting widespread degradation of groundwater and surface water resources. The Division of Water Quality is currently formulating a permitting process to regulate this waste disposal. Permitting is set to begin in January 2005 and the U.S. Environmental Protection Agency has mandated the permitting of all large facilities by the end of 2006.

Although many poultry litter studies have been conducted in southern states, relatively few have focused on North Carolina. Recent studies were typically performed by university agricultural departments and focused on litter application rates and management practices to maximize fertilizer capability and minimize runoff. However, few studies analyzed resultant groundwater degradation, with only one known study that involved monitoring well installation.

With North Carolina’s upcoming program to grant permits for these disposal activities, now is an excellent time to conduct a shallow groundwater susceptibility study in the areas most affected by this growing industry. The study will include the following:
• Apply findings from other Piedmont-Mountains Study research to produce site conceptual models which will help characterize local groundwater conditions and guide the investigation;

• Install one to three shallow monitoring wells on several fields that are representative of the geology, soil types and geomorphology in the area. These fields may be currently in use as litter disposal sites (and may have been used for this purpose for several decades), they may be proposed as future sites, or they may be unused and chosen for their “background” conditions;

• Establish groundwater flow directions and sample the wells for nitrogen, phosphorus and metals (the most common constituents of concern found in litter). This data can be combined with existing soil data collected from disposal fields by other agencies, and with existing soil data collected by Groundwater Section staff for our studies on naturally occurring metals;

• Draw generalizations about the site conditions that are most and least likely to exhibit groundwater problems, if any are found;

• Use the data for scientifically defensible arguments to support permit conditions intended to protect groundwater quality.

Other Activities

Piedmont-Mountains Study personnel have given numerous presentations on our work to a diverse selection of audiences over the last few years. This type of educational outreach and transfer of information will continue, and will become especially important as we conduct thorough analyses of our data and are able to recommend changes to NCDENR policies, guidelines and rules. The Resource Evaluation staff is also tasked with performing pollution incident management and permit reviews, so this work will also be used in daily context at the regional level to support decisions in those program areas.

Mooresville Regional Office

Langtree Peninsula
Lake Norman, Iredell County

The Langtree Peninsula hydrogeological research station is located on the Davidson College Lake Campus, adjacent to Lake Norman. Geological mapping, well installation, aquifer testing, slug testing, and groundwater sampling (Figure 4) have been completed. Upcoming work is scheduled and involves the following: packer testing to determine the hydraulic properties of rock fractures; additional aquifer testing to assess groundwater and lake water interactions; subsurface dye tracing to define groundwater flow, recharge, and discharge. Current and future “maintenance” activities for the next several years will include periodic well sampling to monitor temporal changes in
groundwater quality, educational outreach activities to accommodate visits by high school and college groups, and training exercises for Groundwater Section personnel.

**Allison Woods Recreational Area**
*Statesville, Iredell County*

The next research station for the Mooresville Regional Office will be located within the Allison Woods Recreational Area. Coordination with Allison Woods staff is nearly complete and site walks by Groundwater Section hydrogeologists and drilling personnel have delineated well installation locations. Additionally, initial geological mapping is underway, which will allow for efficient field activities and related data collection. The Mooresville Regional staff has developed information from these reconnaissance activities into a series of hydrogeologic exercises for high school students, which will be implemented into the local, public school Earth Science curriculum.

![Figure 3. Langtree Peninsula Research Station groundwater quality. Although additional impurities were discovered, only those parameters exceeding 2L standards are shown.](image)

Upcoming field activities for the Allison Woods site will include, but not be limited to rock coring, monitoring well installation, geophysical surveys, slug testing, aquifer testing, and groundwater sampling. Information from this station, combined with data obtained from the Langtree Peninsula site will provide valuable insight at the regional level to support decisions related to NCDENR/DWQ policy, pollution incident management, and permit reviews.

**Pasour Mountain Resource Recovery Farm**
*Bessemer City, Gaston County*

Pasour Mountain is the location of an older, Groundwater Section study to provide hydrogeologic and geologic data for the Environmental Protection Agencies’ (EPA) Long Creek Watershed Study. This study site is located at the Pasour Mountain
Resource Recovery Farm, a 700-acre property owned and operated by the City of Gastonia for the land application of biosolids. Previous work at the site involved the installation of monitoring wells along a transect from the base of Pasour Mountain westward to the boundary of the study area to characterize the hydrologic setting of the basin and to determine the groundwater recharge rate.

A new study has been initiated at the Pasour Mountain site, which will segue with the Arsenic Study (see below) that is currently underway in the Mooresville Region. The new study will be the compilation of two smaller studies:

- **Tile Study** – In cooperation with the NCGS, ceramic tiles have been deployed in streams located within the Pasour Mountain site boundaries. Over time oxyhydroxide coatings will form on the tiles. Periodic harvesting of the tiles over the next 6 months and subsequent analysis will reveal base metal concentrations that precipitate out of solution as groundwater enters the surface water system. A plot of the preliminary data is shown in Figure 4. The results of this study could have implications for permitted activities around baseflow streams. Additionally, plans are being developed to deploy the tiles in active domestic water supply wells.

- **Sediment Load Study** – analysis of sediment collected from the streambed versus stream load sediment collected during storm events should reveal anthropogenic sources of base metal concentrations in stream sediments. Sediment samples collected from a streambed and those collected as suspended sediment during storm events should reveal anthropogenic input when compared to the crustal average (or local average) for select base metals. The application of alum to the soils in at the Pasour Mountain Resource Recovery Farm, make this an ideal location to test this method. If successful, the technique could be applied to other areas where anthropogenic sources for contaminants might exist (i.e. application of arsenic bearing pesticides/herbicides).
The new Pasour Mountain project is a pilot study to evaluate two techniques that may allow us to better understand 1) the chemical processes occurring at the groundwater/surface water interface or similarly, chemical processes occurring when groundwater enters a pumped well; and 2) the fate and transport of chemicals applied to the ground surface.

Additional Research

Studies conducted by the Mooresville Regional Office have revealed arsenic contaminated groundwater in various water supply wells in the south central Piedmont (Pippin, 2003). A joint investigation between the Mooresville staff, the Central Office, North Carolina Geological Survey, and North Carolina State University is now underway to analyze rock core from Montgomery and Davidson Counties to determine if this contamination is naturally occurring, and its possible geologic source. Current and future well sampling activities will be combined in a joint effort with the North Carolina Department of Health and Human Services to develop an arsenic database, which will delineate locations of potentially hazardous arsenic contaminated groundwater. Finally,
funding for a radiometric isotope groundwater research project is being secured, to assess the potential health threat to citizens within the Mooresville and Asheville Regions.

**Asheville Regional Office Research Stations**

*Bent Creek*
*Asheville, Buncombe County*

The Bent Creek research station is within an undeveloped watershed located within the Bent Creek Experimental Forest. This site serves as a baseline example of “natural” groundwater occurrence, flow, and quality and will provide valuable information for comparison to more developed areas, underlain by similar geology. Geological analysis and mapping has been completed, along with geophysical surveys and monitoring well installation. Current work is focused on the analysis of recently collected groundwater and surface water samples.

Activities planned for the next several years will focus on the long-term evaluation of groundwater quality and its relationship to land use. Representative watersheds of similar characteristics – developed and undeveloped - will be assessed, and water quality and contaminant transport mechanisms will be analyzed. Specific, related fieldwork for the Bent Creek station will include the following: periodic collection and analysis of groundwater and surface water samples to establish long-term trends; implementation of slug and aquifer testing to assess groundwater flow and storage properties; and the analysis of all hydrogeological data to determine the relationship of groundwater and surface water interactions.

*Highlands Research Station*
*Asheville, Buncombe County*

Asheville Regional staff is developing plans for the Highlands Research Station, which will be installed within a developed watershed with geology similar to the Bent Creek Station. Although a research site has yet to be selected, coordination between Asheville staff and local property owners is underway. Once established, field research, similar to the Bent Creek site will be conducted to collect and analyze hydrogeological data. Results from this study, in conjunction with Bent Creek information should lend valuable insight into the impact of land use on groundwater and surface water occurrence, availability, flow, and quality.

*Anthropogenic Contaminant Research*

Identifying the source of a contaminant release, determining its nature and extent, and providing a remedial strategy all require a thorough understanding of the hydrogeologic setting and the dynamics of ground water flow. Unfortunately, contaminant flow and transport in the fractured rock aquifers are of Western NC are complex and poorly understood. Groundwater pollution research will advance our
understanding of contamination in fractured rock and address specific, selected issues related to the investigation and remediation of these contaminant releases.

Two types of contamination are particularly problematic in the Asheville Region. Historic solvent releases from industrial sites are widespread and contribute to persistent, long-term degradation of the shallow and deep ground water supply. Petroleum hydrocarbon releases from large capacity bulk plant storage facilities also are common and contribute to degradation of the shallow ground water supply.

A representative chlorinated solvent site(s) and a petroleum hydrocarbon site(s) will be selected and studied as part of this research. Research focus will involve the following goals:

- Determine the reliability and repeatability of slug tests used to obtain hydraulic conductivities (current estimates often vary widely and greatly affect estimates of contaminant travel times);
- Determine the effects of major geologic structures (faults, for example) on contaminant movement;
- Determine the effects of soil type (saprolite vs transition zone) on contaminant movement;
- Determine the extent of contaminant movement in various hydrogeologic settings.

Other Activities

The Asheville Regional Office is developing a groundwater study to evaluate potential arsenic contamination, which would supplement related studies currently underway. Additionally, a radiometric isotope groundwater research project, in joint cooperation with the Mooresville Regional Office, is also being developed. This study will assess and document the occurrence and distribution of radionuclides in groundwater and indoor air in western North Carolina. The respective proposal has been written and is currently under review by Groundwater Section staff.

References


Pippin, C.G. et.al., 2003 Distribution of Total Arsenic in Groundwater in the North Carolina Piedmont, Staff Report, North Carolina Department of Environment and Natural Resources, Division of Water Quality, Groundwater Section, report available at http://www.mro.enr.state.nc.us/gw/