Department *of* Environment, Agriculture, Parks & Recreation

2013 Annual Report

Orange Well Net

The Orange County Groundwater Observation Well Network

August 2013

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Acknowledgements

This project has been greatly aided by the assistance of the following:

- Association for the Preservation of the Eno River
- Duke Forest
- North Carolina Department of Environment and Natural Resources - Division of Water Resources and the Division of Water Quality
- North Carolina Geological Survey, in particular, Mr. Phil Bradley, Senior Piedmont Geologist
- United States Geological Survey, North Carolina Water Science Center
- Mr. William Kaiser

Cover: Bedrock well
4D in Duke Forest.

I. Introduction

In May 2005, the adopted Water Resources Initiative proposed the creation of a groundwater observation well network in Orange County to continue the work of the previous decade of groundwater research in the county, and provide a network for the collection of information on local groundwater quality and quantity.

As shown in Figure 1 below, groundwater in the Piedmont region of North Carolina (including Orange County) is found within fractured bedrock as well as in the overlying unconsolidated material, which is known as regolith. Older hand dug and bored wells accessed the groundwater present in the near-surface regolith, but because of the shallow depth, this water often contained bacteria and other contaminants originating from the surface. More recent water wells are drilled into the deeper fractured bedrock aquifer. The groundwater present in bedrock wells originates from within the fractures present in the bedrock. Hydrogeologists often refer to regolith groundwater as water that is in storage since it is this water that recharges the deeper fractured bedrock aquifer that is tapped by newer water wells.

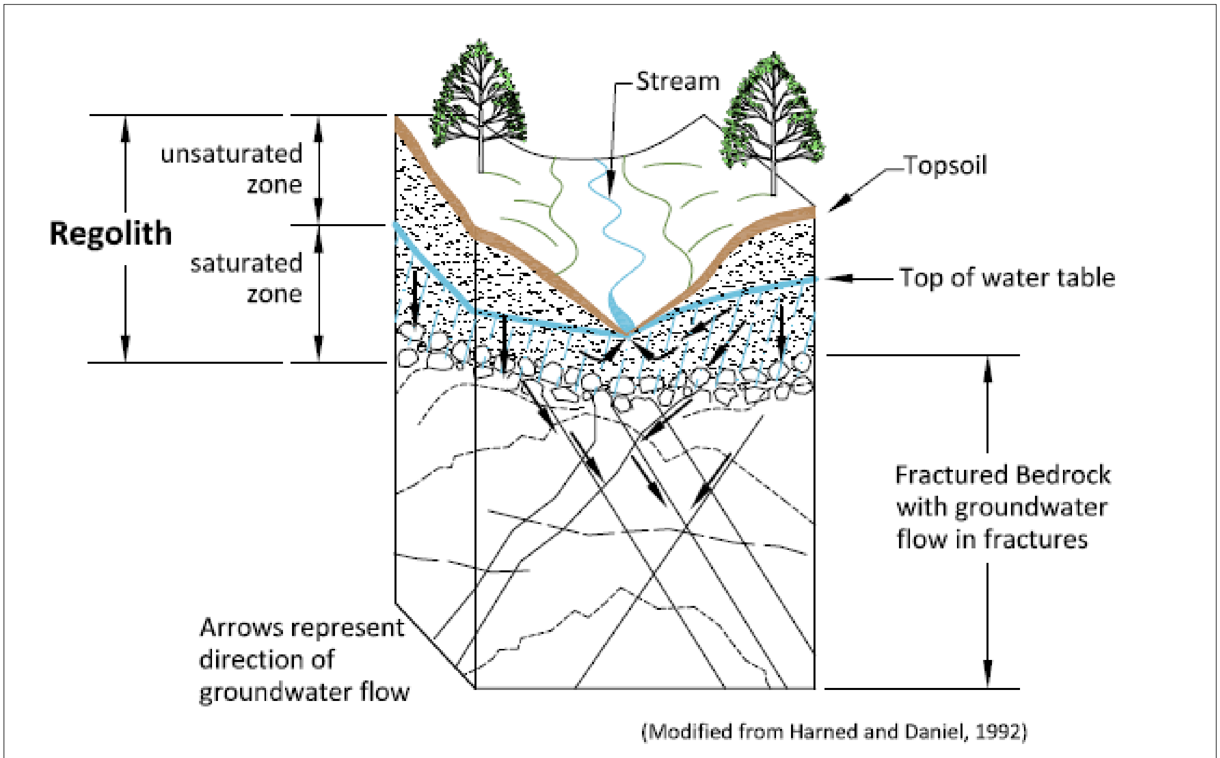


Figure 1. Schematic diagram illustrating the movement of groundwater in the Piedmont region of North Carolina.

The goals of the groundwater observation well network include the collection of groundwater level data from a combination of bedrock and regolith wells spread across the nine main types of generalized bedrock geology present in Orange County. Regolith wells, completed in the near-surface unconsolidated material that is present above bedrock, are designed to monitor natural stresses on the quantity of groundwater available in storage that are caused by variations in climatic conditions. Bedrock wells are utilized to monitor changes in groundwater levels in the bedrock across the county. Taken together, the Orange Well Net (OWN) is designed to collect information concerning the amount of groundwater available locally in Orange County.

II. Project Progress

Early in the project, a decision was made to identify and utilize existing bedrock wells instead of incurring the expense of installing new wells. Six out-of-use bedrock wells were secured for use in OWN and groundwater level data collection began in late March 2010. In June 2011 a cooperative arrangement allowed Orange County to begin utilizing three regolith wells for the collection of groundwater level data from the shallow aquifer.

In 2012, two bedrock wells, the Ray Road and Rocky Ridge wells, were removed from the network and two replacement bedrock wells, well 4D in Duke Forest and a well at the former Orange County 911 Center were added to OWN. Table 1 lists the well construction details for the Orange Well Net wells. Figure 2 illustrates the locations of the wells. Figure 3 illustrates the locations of the wells in relation to the generalized bedrock geology of Orange County.

Staff downloads groundwater level data periodically from each of the observation wells in Orange Well Net. The collected data is formatted and then uploaded to the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Resources (DWR) groundwater level database web site:

http://www.ncwater.org/Data_and_Modeling/Ground_Water_Databases/leveltable.php?tl=1&net=orange&inactive=

This web site is available to the general public and includes significant information regarding groundwater level conditions across North Carolina, as well as the information collected in Orange County through the use of Orange Well Net.

III. Groundwater Level Data

The groundwater level information collected from each of the three regolith and six bedrock observation wells is included in Figures 4 and 5 and can also be viewed at the above listed DWR web site. The hydrographs, or groundwater level records, for all of the bedrock wells except 4D and the well at the former 911 Center cover the interval from when automated data collection began at the beginning of this project in 2010 through June 2013.

Manual data collection was initiated in 2008 in well 4D only, and as a result, the hydrograph for well 4D includes a longer period of time than those for the other bedrock wells. The smooth nature of the 4D groundwater level record from 2008 through most of 2012, versus the more jagged aspect since late 2012, reflects the change from manual data retrieval from 2008 through 2012 to the onset of automated data collection in late 2012.

The hydrograph for the bedrock well located at the former Orange County 911 Center is not included in this report since data collection at this location only began in October 2012. The hydrograph for this well will be included in subsequent OWN reports.

Table 1. Orange Well Net Well Details.

Bedrock Wells					
	Bedrock Well Location	**Casing Depth, ft.**	**Total Depth, ft.**	**Top of Casing Elevation, ft.**	**Bedrock Geology**
1	Millhouse Rd	67	164.7	515.22[1]	Metasedimentary rocks (Epiclastics)
2	Eno Confluence	37	175.5	609.27	Pyroclastic rocks (Felsic tuff)
3	Former 911 center	85	400	581	Altered Pyroclastic rocks (Altered tuff)
4	Blackwood Farm	100	302	557.44	Felsic lavas and tuffs (Dacite)
5	Duke Forest 4D	87.9	402.9	427.82	Felsic intrusive (Granodiorite)
6	Eubanks Road	33	145.7	531.15	Mafic intrusives (Gabbro)

Regolith Wells				
	Regolith Well Location	**Total Depth, ft.**	**Top of Casing Elevation, ft.**	**Geology**
1	Andrews Rd. (COL-1)	33.0	528.00[1]	Regolith overlying felsic tuff bedrock
2	Hwy 54 (COL-3)	43.7	528.18[1]	Regolith overlying diabase bedrock
3	Orange Grove Road (COL-4)	35.2	504.86[1]	Regolith overlying diabase bedrock

1– Estimated elevations.

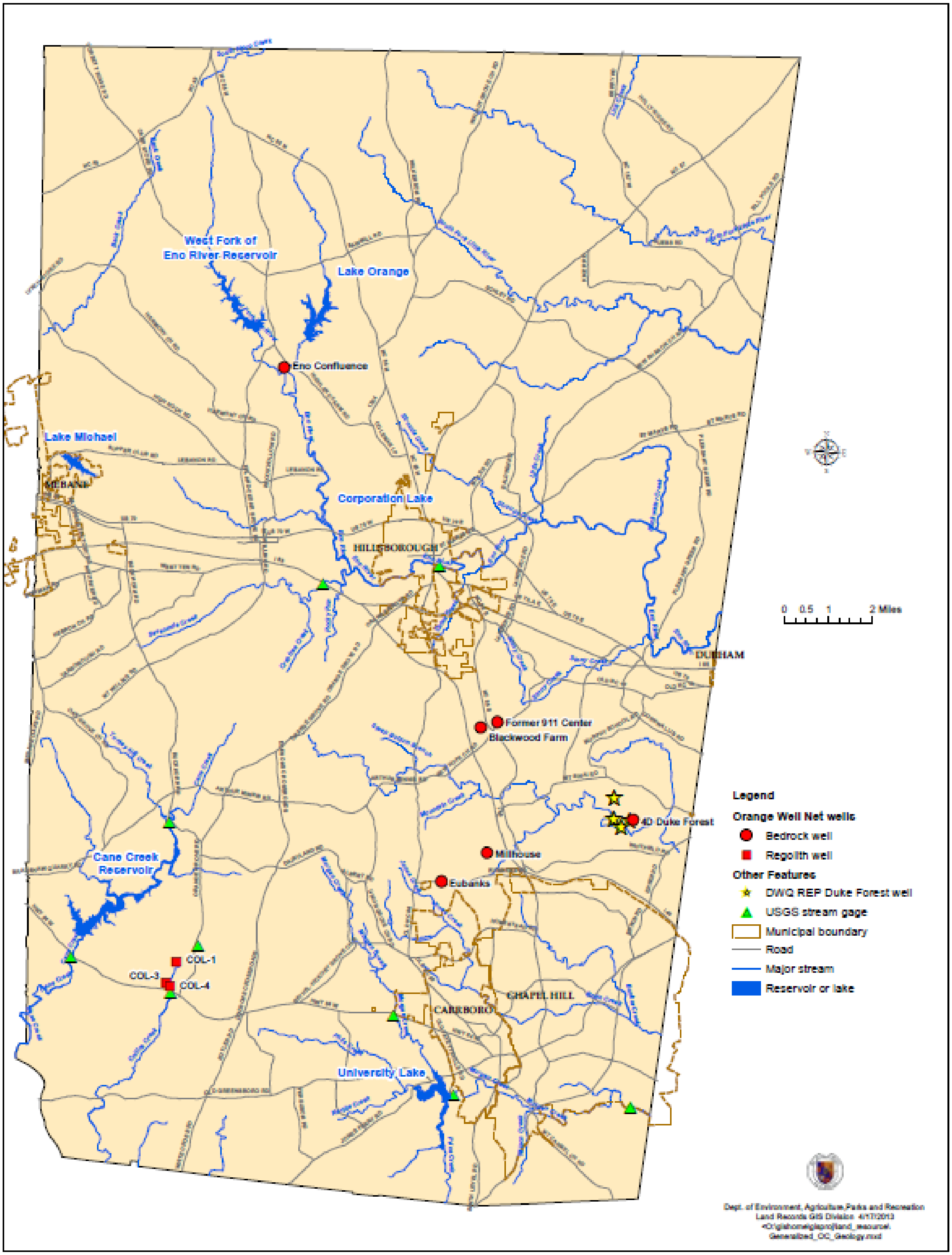


Figure 2. Map of Orange County showing the Locations of Orange Well Net Groundwater Observation Wells.

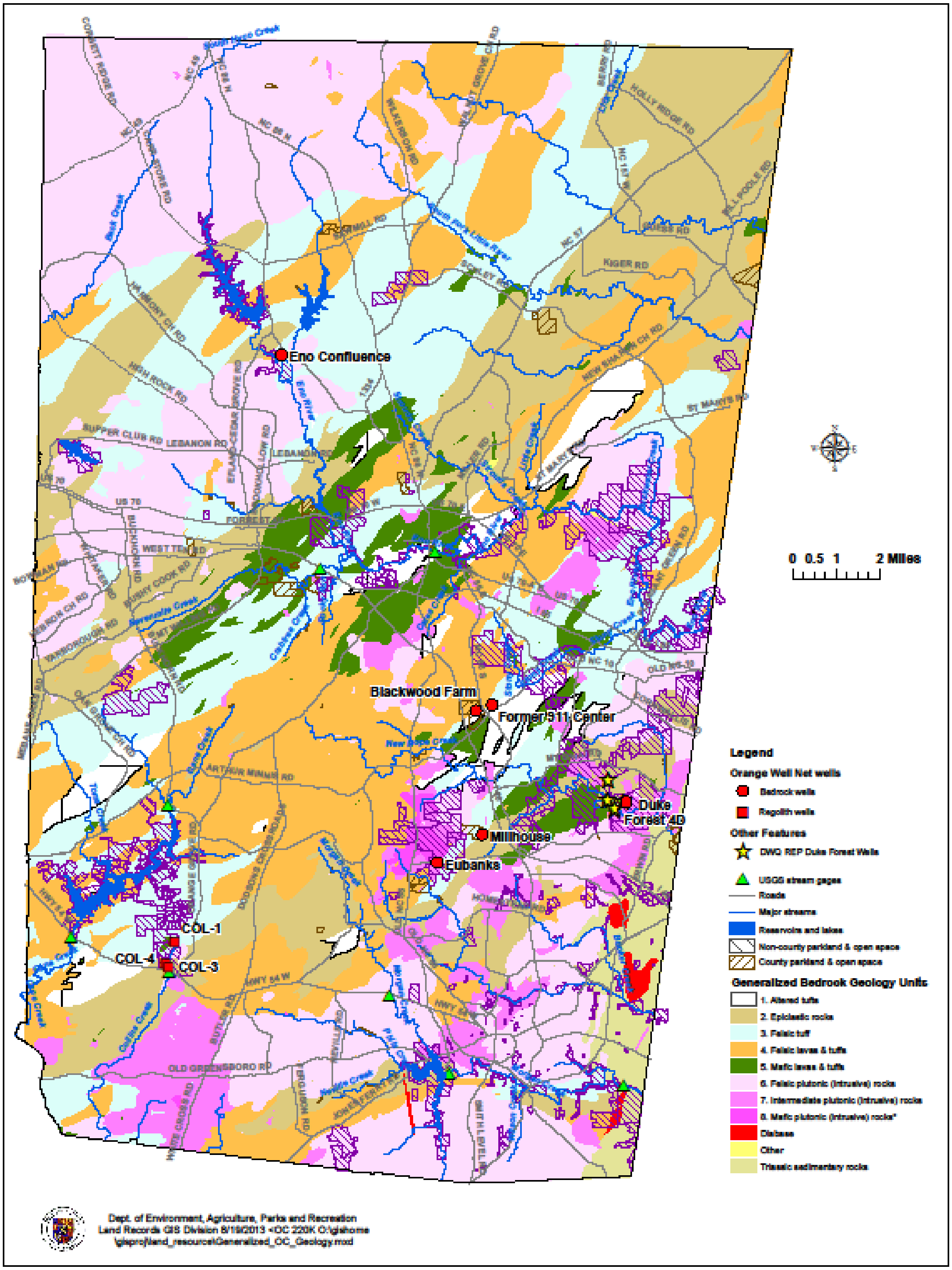


Figure 3. Generalized Geologic Map of Orange County with Locations of Orange Well Net Regolith and Bedrock Wells.

A. Regolith Groundwater Data Observations

Groundwater level data collected from the three regolith wells included in OWN depict the same general overall end result, namely very little net change in groundwater elevation over the course of 2012 (Figure 4). There was however, considerable variation in the groundwater elevations in all of the wells over the year, as well as comparative differences amongst the three hydrographs throughout the year. The COL-1 hydrograph indicates net groundwater recharge in 2012 occurred from January until the end of March and then again from September through the end of December. Groundwater elevation in this well fell from April through the end of June. COL-3 experienced no significant recharge during the early 2012 and, somewhat surprisingly, an increase in groundwater elevation occurred in July and August. In addition, during 2012, the groundwater elevation in this well decreased from September through the end of December. The COL-4 hydrograph is very similar to that of COL-3. Well COL-4 also underwent little recharge during early 2012 and experienced a more substantial period of recharge in July and August. The groundwater elevation in COL-4 fell from April through June as well as from October through the end of November.

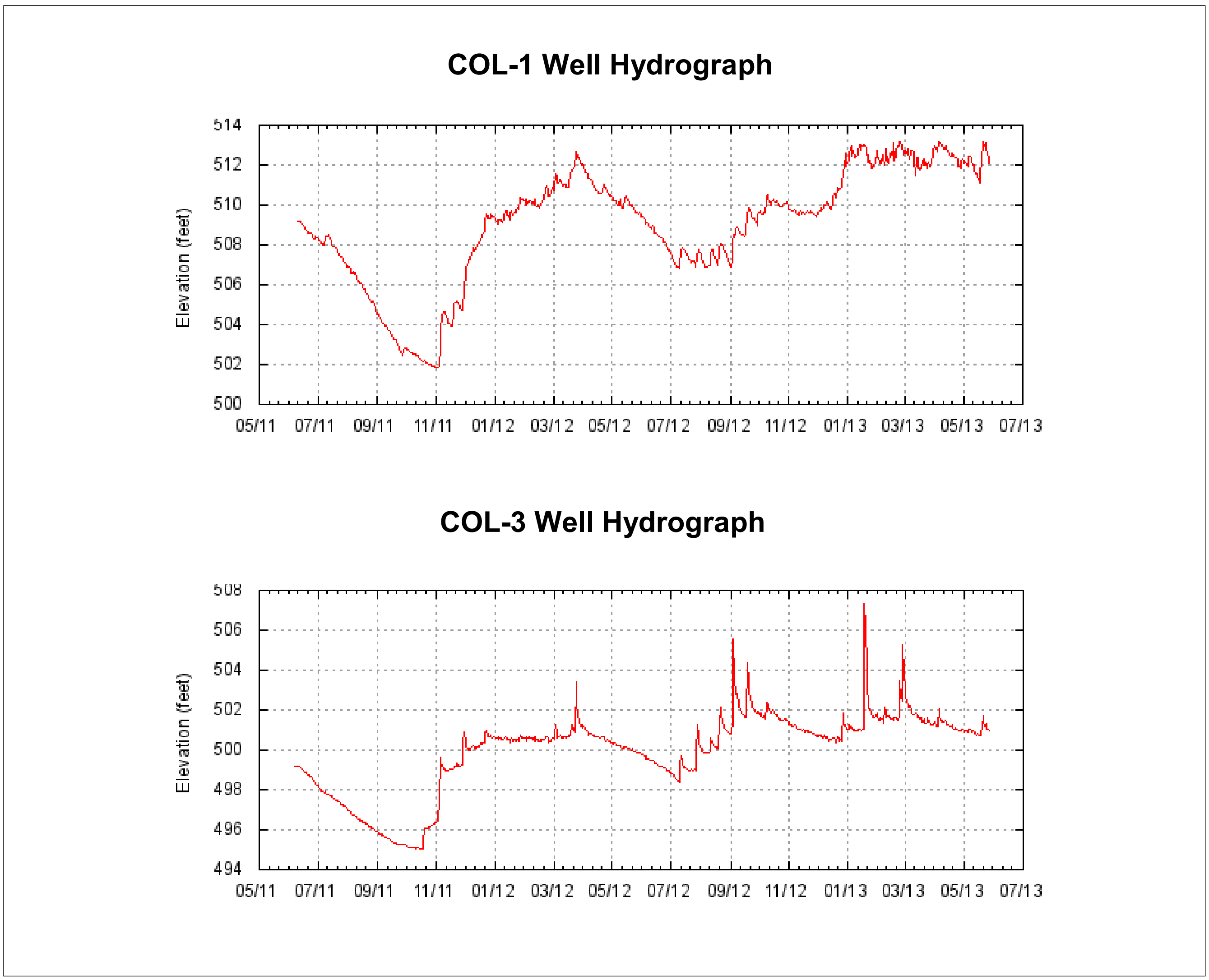


Figure 4. OWN Regolith Well Hydrographs.

COL-4 Well Hydrograph

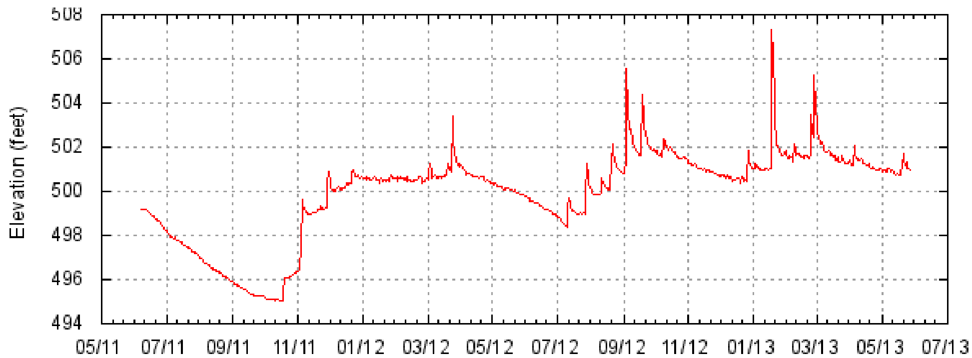


Figure 4 continued. OWN Regolith Well Hydrographs.

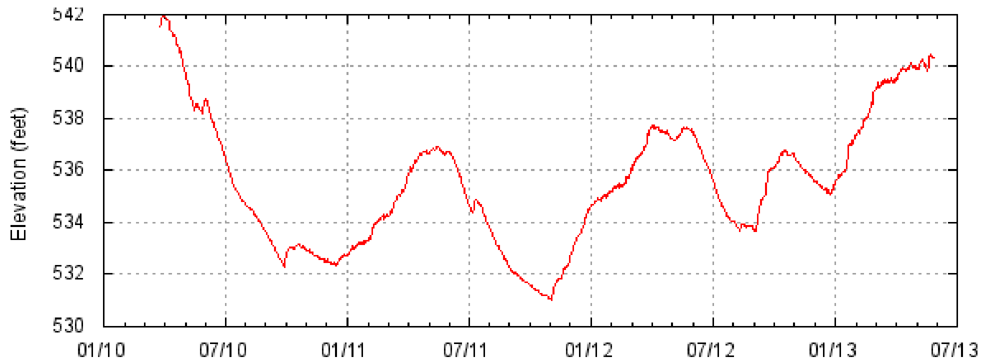
B. Bedrock Groundwater Data Observations

Data collected since the initiation of this project in 2010 demonstrates that the net amount of groundwater recharge in the bedrock aquifer that took place over the winter of 2011-2012 was very similar to that which occurred the previous year (Figure 5). Groundwater levels rose approximately six feet in all of the bedrock wells except Duke Forest 4D and the Eno Confluence property wells. Much less recharge, only 2 feet, took place in these bedrock wells. In addition, starting in June 2012, bedrock groundwater levels decreased throughout the remainder of the year except for a small increase in September and October 2012. Finally, the groundwater level in the Eno Confluence well fluctuated much more quickly than what was observed in the other bedrock wells.

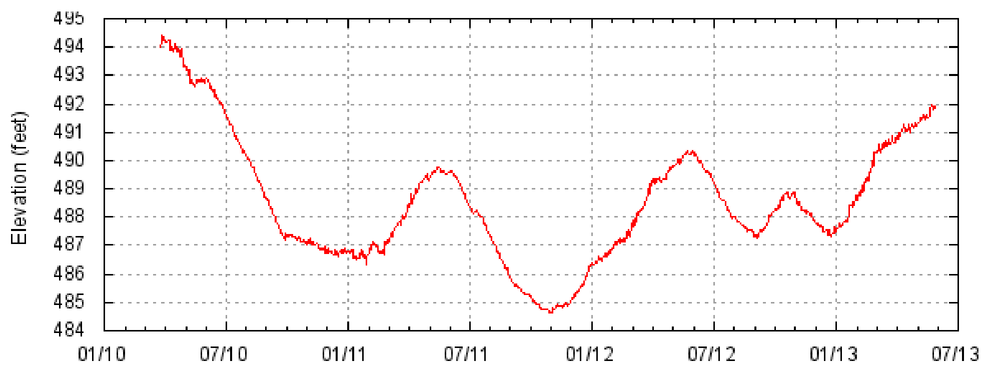
Eubanks Road Well Hydrograph

Figure 5. OWN Bedrock Well Hydrographs.

Blackwood Farm Well Hydrograph



Millhouse Road Well Hydrograph



Duke Forest Well 4D Hydrograph

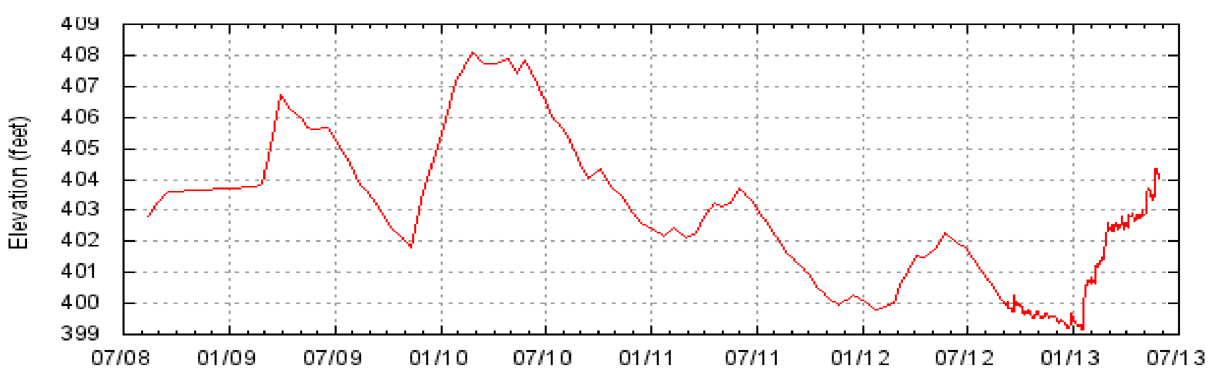


Figure 5 continued. OWN Bedrock Well Hydrographs.

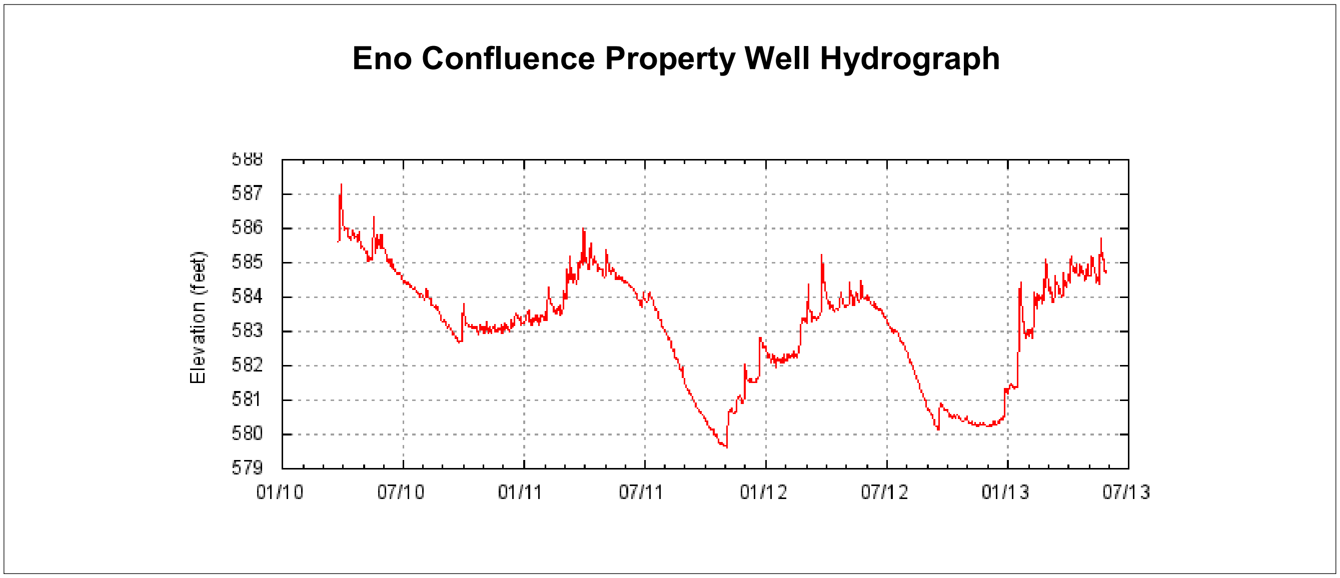


Figure 5 continued. OWN Bedrock Well Hydrographs.

IV. Groundwater Data Discussion

Groundwater levels typically fall during the months of the growing season, due to a reduction in groundwater recharge. Groundwater recharge is reduced in part due to increased evaporation as a result of higher ambient temperatures. Another important factor in decreasing recharge is the increased use of water by plants during the growing season (transpiration). These factors normally result in significantly lower groundwater levels during the summer months in North Carolina. The non-growing season, November through March, is the period during which most significant groundwater recharge occurs. Recharge takes place when precipitation infiltrates into the ground and reaches the water table, rather than evaporating, being used by plants, or exiting the system as runoff. Infiltration increases the amount of groundwater held in storage, raising groundwater levels in the regolith (upper) aquifer and then the underlying bedrock aquifer. Typically this recharge is then available for use during the subsequent growing season. Periods of drought or dry weather can, of course, reduce recharge which could then impact the amount of groundwater available during the growing season.

According to the USGS rain gage located near regolith well COL-1 in southern Orange County, approximately 35 inches of precipitation fell at that location during 2012 (Figure 6). Information from the State Climate Office indicates that the total average annual precipitation in Orange County is 47.6 inches. This information indicates that the amount of precipitation that fell at the USGS rain gage in proximity of the OWN regolith wells was approximately 75% of the normal amount. Figure 7 estimates that the amount of precipitation that fell throughout Orange County during 2012 ranged from 75 to 100% of the typical average amount. This is consistent with the measurement obtained at the USGS rain gage as well as the data that was collected at the weather station located at Horace Williams Airport in Chapel Hill (42.4 inches of precipitation in 2012). In total, this information indicates that Orange County experienced slightly decreased total precipitation during 2012.

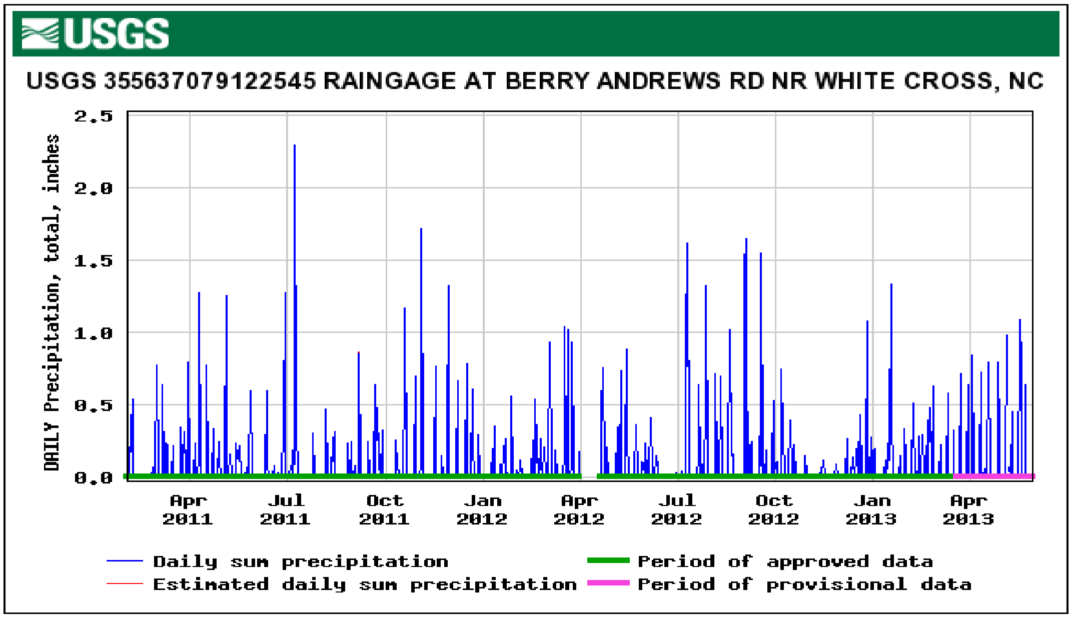


Figure 6. Graph of Precipitation Recorded at Raingage Located in the Vicinity of OWN Regolith Well COL-1.
Source: United States Geological Survey web site.

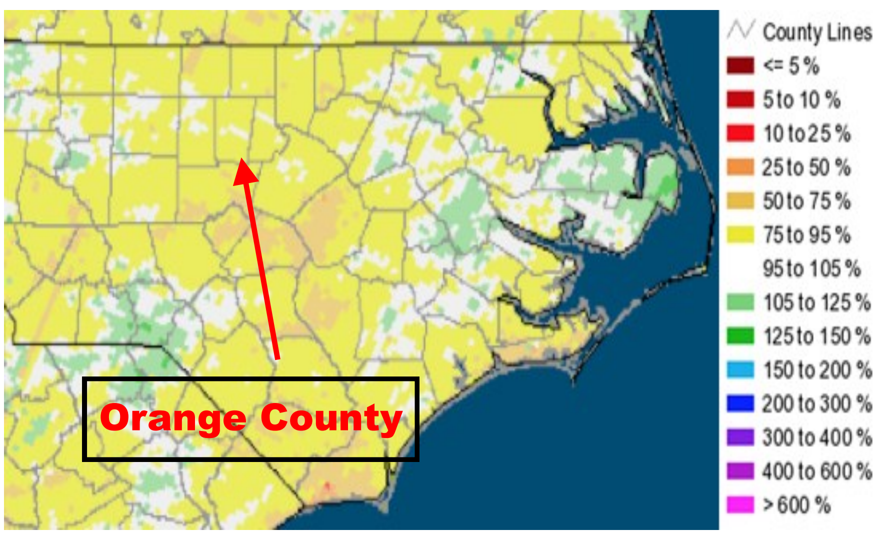


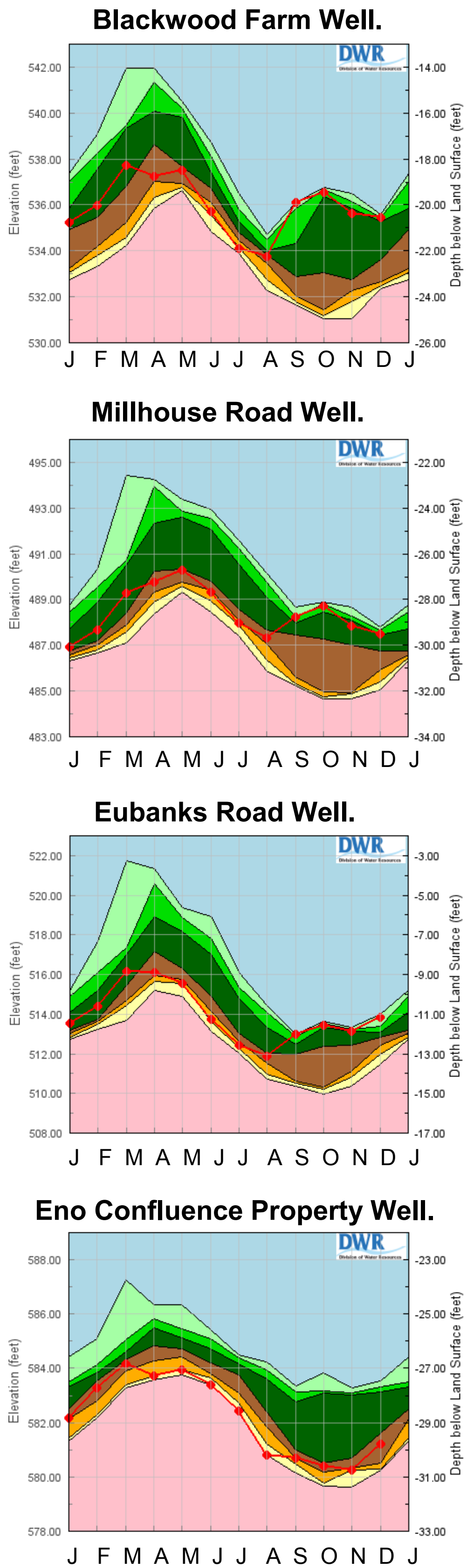
Figure 7. 2012 Annual Precipitation Percent of Normal.
Source: State Climate Office of North Carolina web site.
Based on estimates from NWS Radar. Data courtesy NWS/NCEP.

As discussed previously, the decrease in bedrock groundwater levels during the summer growing season of 2012 is expected. The small increase in groundwater levels in September and October 2012 is likely the result of consistent rain during the July through October 2012 period as shown in Figure 6. This rainfall led to an increase in groundwater levels in regolith wells COL-3 and COL-4 in July and August, and then shortly thereafter, in September and October an increase in bedrock groundwater levels, as shown in all of the bedrock well hydrographs except those for 4D and the Eno Confluence well.

Study of the regolith well hydrographs indicates seasonal differences amongst these wells in their response to precipitation. COL-1 experienced an increase in the groundwater level during early 2012. The hydrographs for COL-3 and COL-4 do not demonstrate a similar response, instead they display short term spikes in their records with no net increase in groundwater level over this time period. The hydrographs for COL-3 and 4 do however exhibit increases in groundwater levels in July and August 2012, as discussed previously. In addition, the COL-1 hydrograph shows an interesting oscillation during the summer of 2012 with no net increase in groundwater elevation.

Closer examination reveals significant differences in the responses of the regolith wells to precipitation events. The response of COL-1 to precipitation events seems lessened when compared to the other two regolith wells (COL-3 and COL-4). This is likely due to the different soil types at these locations, which reflect differences in the underlying geology. COL-1 is underlain by rock that is rhyolite to granite in composition while the other two regolith wells are underlain by diabase rock. The soils that formed from the diabase rock seem to possess a higher hydraulic conductivity than the soil at COL-1. Hydraulic conductivity is a measure of the ability of fluids to move through the pore spaces and fractures in subsurface materials. These variations in conductivity indicate that groundwater moves quicker through the regolith at wells COL-3 and COL-4 than it does at COL-1, as illustrated by the numerous spikes in the COL-3 and COL-4 hydrographs versus the smaller more rounded bumps in the COL-1 hydrograph. In addition, the fact that the groundwater in the vicinity of COL-1 is typically much closer to the surface than it is at the other regolith wells may also indicate lower conductivity in the regolith near COL-1, since lower conductivity increases the amount of time it takes for groundwater to move downward through the regolith. Finally, the diabase rock present in the vicinity of wells COL-3 and COL-4 is also likely more heavily fractured than the felsic rock in the vicinity of COL-1. Fractures can greatly increase the hydraulic conductivity of the subsurface.

Overall, bedrock groundwater levels over the course of 2012 increased slightly above 2011 but remained below the levels measured when data collection began in 2010. It is not known if the groundwater levels measured in 2010 were abnormally high or are actually closer to the norm. Further data collection will help define the longer term trends of groundwater in Orange County. Once the period of a hydrograph is at least 12 months long, statistical evaluation of water levels on the DWR web site can be conducted. Figure 8 contains statistical graphs for the 2012 groundwater levels for four of the OWN bedrock wells. The longer the period of record for a well, the more robust the statistical analysis of the record becomes. In general, the statistical analyses included in Figure 8 cover less than a three year time interval, but they demonstrate that bedrock groundwater levels typically increase and peak within the first five months of each calendar year as a result of recharge. Bedrock groundwater levels then fall through the growing season and close out the calendar year with a small increase. The Blackwood Farm, Millhouse and Eubanks Road bedrock wells included in Figure 8 illustrate that the groundwater levels in these wells during 2012 were above the median in the spring and fall months and below the median during the growing season. The median (or 50th percentile) groundwater level over the course of the year is represented on each graph by the black line that separates the brown (25th to 50th percentile) and dark green (50th to 75th percentile) colored portions of each of the graphs. The record for the Eno Confluence property well demonstrates that the groundwater level was never above the statistical median during 2012. No statistical graphs for the regolith wells are included in this report at this time due to the short period of record for these wells.



2012 STATISTICS:

- Above Monthly Maximum
- Above 90th Percentile
- 75th - 90th Percentile
- 50th - 75th Percentile
- 25th - 50th Percentile
- 10th - 25th Percentile
- Below 10th Percentile
- Below Monthly Minimum
- Year of Interest Levels

Notes:

1. The median is represented by the black line on all graphs between the areas identified as 25th - 50th percentile and 50th – 75th percentile.

2. Year of Interest Level is 2012.

3. Statistics through May 2013.

Figure 8. OWN Bedrock Well 2012 Groundwater Statistical Graphs.
Source: NC Division of Water Resources web site.

Finally, the Eno Confluence bedrock well hydrograph appears noticeably different from the other bedrock well hydrographs. This well is located in proximity to both the West and the East Forks of the Eno River. The hydrograph for this well reflects a considerable amount of "flashiness" (rapid fluctuations, either up or down, in a short period of time) in the groundwater level. This is likely the result of quick increases and decreases in the flow of the Eno River as a result of precipitation in the upper Eno River watershed, indicating that the groundwater level in the area of this well is fairly quickly influenced by the water level in the Eno River.

Recommendations

- Groundwater level information should continue to be collected from the regolith and bedrock observation wells in Orange Well Net. Currently, routine data collection from the bedrock and regolith wells is occurring and little additional expense is needed at this time to continue this process. The collection of additional data from each of the observation wells will permit further evaluation of long-term groundwater trends in Orange County.

- Continue to upload groundwater level information to the DWR web site. This will allow the public to have no-cost access to the groundwater level information collected in Orange County.

- Continue to conduct statistical analyses as additional groundwater level data is collected from OWN.

- Pursue the addition of more bedrock and regolith observation wells to Orange Well Net. The use of additional existing out-of-service wells should be explored as a low-cost means of expanding the observation well network.

- The use of a co-located bedrock and regolith well pair would be a valuable addition to OWN. A pair of wells in the same location would provide detailed information concerning groundwater recharge and groundwater level response to precipitation events.

- Additional regolith wells will aid in the study of groundwater response to precipitation events such that analysis of the influence of differences in bedrock geology to groundwater levels over time may be possible.

- It is expected that the USGS rain gage located in the vicinity of the regolith wells will be deactivated in the near future, meaning no further precipitation data will be collected by this instrument. A replacement rain gage would be a valuable addition to OWN. Installation of a rain gage at the location of a regolith and bedrock well pair would be especially beneficial.

- When possible, continue to publicize Orange Well Net as a means of increasing citizen knowledge of the importance of groundwater in Orange County. As more groundwater level information is collected, further use of the Orange Well Net data available on the DWR web site should be encouraged.