PRELIMINARY HYDROGEOLOGIC INVESTIGATION FOR THE PROPOSED SNOW CAMP QUARRY SNOW CAMP, ALAMANCE COUNTY, NORTH CAROLINA

Prepared for:
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September 22, 2018

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Executive Summary

Geologists have completed a preliminary hydrogeologic study in the vicinity of the proposed Snow Camp Quarry located between Clark Road and Quackenbush road, approximately 2 miles south of the unincorporated town of Snow Camp in Alamance County, North Carolina. The preliminary investigation is based on information provided by Carolina Geological Services, Inc. and Snow Camp Property Investments to support work in the preliminary permitting process for the proposed quarry. The scope of work primarily included the compilation of existing data and the evaluation of new data and field observations collected during site visits. This report describes the hydrogeology of the area and potential impacts of quarry development on local ground- water resources. Based on this preliminary study, the following conclusions were reached:

The proposed Snow Camp Quarry and any the water supply wells in the area receive their groundwater from interconnected fractures in metamorphic or igneous bedrock. In general, most of these fractures occur in the upper 30 to 50 feet of bedrock, although water-bearing fractures could occur deeper in wells or in the quarry pit walls. The majority of drilled water supply wells in the area tend to be constructed in fractured bedrock although some shallow wells may be completed in the overlying saprolite. Well yields tend to be approximately the same in both rock and sand wells, ranging from 1 to 30 gallons per minute. Most of the wells in the area are around 100 feet deep. There are currently 2 inactive water supply wells and 1 active water supply well on the subject property. The nearest active water supply well not on the subject property is located approximately 500 feet west/southwest from the proposed quarry.

The geological data and literature indicate it is not likely that the water table in residential water supply wells located more than 500 feet away from the proposed Snow Camp Quarry pit wall would be adversely impacted by the quarry operation. Also, it is not likely that groundwater levels will be influenced in any way by groundwater withdrawals at the proposed quarry at a distance of 1,000 feet from the proposed quarry walls. This conclusion is based on a review of available information obtained during this preliminary investigation, including a comparison of conditions at other quarries with similar geologic and hydrogeologic conditions. Comparative information was reviewed from North Carolina Division of Environmental Quality files for the Burlington quarry East Alamance quarry. A detailed hydrogeologic study of the proposed Snow Camp Quarry area has not been performed. However, it is likely that the impact to groundwater resources in the proposed Snow Camp Quarry area will be similar to impacts experienced at these nearby quarries with similar geologic and hydrogeologic conditions.

A limited fracture trace analysis was performed for the area surrounding the subject site and determined the following: the fracture trace analysis gives some indication of the

density and connectivity of significant fracturing in the shallow bedrock. The fracture density appears to be low and based on the apparent displacement and cut-off of foliation, the interconnectivity of the fracture sets does not likely extend over distances. Therefore, one can expect little to no impact to groundwater resources beyond the property boundaries. The existing water supply wells located on the property appear to be ideally situated for conversion to monitoring wells and beginning a groundwater monitoring program.

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PRELIMINARY HYDROGEOLOGIC INVESTIGATION FOR THE PROPOSED SNOW CAMP QUARRY SNOW CAMP, ALAMANCE COUNTY, NORTH CAROLINA

Introduction

The proposed Snow Camp Quarry is located between Clark Road and Quackenbush road, approximately 2 miles south of the unincorporated town of Snow Camp in Alamance County, North Carolina (**Figure 1**). Robert C. Reinhardt, a North Carolina Licensed Professional Geologist, was contracted by Carolina Geological Services, Inc. to provide a general hydrogeologic description of the proposed quarry site, discuss the possible impact of the quarry operation on local groundwater resources, and propose a groundwater monitoring program for the site.

Scope of Work

The scope of services primarily included the compilation of existing data, the evaluation of that data in light of new data and field observations collected during site visits, and a brief report describing the hydrogeology of the area and potential impacts of quarry development on nearby ground water resources. To the extent that the existing and new data allowed, this report summarizes the hydrogeology of the new quarry site with emphasis on the impact of mine dewatering on local surface water and groundwater resources; and provides the framework for a groundwater monitoring program.

This project did not include the installation of monitoring wells, the sampling or laboratory analysis of groundwater samples, or the collection of new data other than field observations and measurements obtained during site visits.

Carolina Geological Services, Inc. (CGS) has provided maps showing the proposed quarry area (**Figure 2**) and the location of existing water supply wells on the property. Snow Camp Property Investments (SCPI), the property owners, provided drill core extracted from the site. SCPI personnel accompanied this geologist to the proposed quarry site to inspect rock outcrops on the property and inspect the existing water supply wells. Published reports from Federal, State and County agencies regarding the hydrogeology, soils, FEMA wetlands, and water availability of the area were searched and reviewed.

This report provides a general hydrogeologic description of groundwater resources in the vicinity of the proposed quarry and a generalized description of groundwater conditions in the Piedmont physiographic region of North Carolina. Based on this review of existing information, this report illustrates the potential impact of groundwater withdrawals from the proposed quarry operation on local groundwater resources.

Regional Geology and Hydrogeology

The proposed Snow Camp Quarry site lies in the Piedmont physiographic province and the eastern edge of the Carolina Slate Belt geologic terrane, and is located just west of the Sanford and Durham Triassic Basins. The near-surface materials of the Piedmont generally consist of a three-stage system that, from top to bottom, contains a regolith zone, a transitional zone, and an underlying fractured bedrock zone (Heath, 1984; Daniel, 1987; Harned, 1989). **Figure 3** demonstrates the important elements of these zones.

The uppermost zone, the regolith, is composed of saprolite (derived from in-place weathering of bedrock), alluvium, and soil. This zone consists of an unconsolidated or semi-consolidated mixture of clay and fragmental material ranging in grain size from silt to boulders. Much of the area near the study site is also covered with a veneer of coastal plain sediments. The upper zone can range from a few feet in thickness to 100 feet or more depending on the rock type and the geologic structure of the rock.

The transitional zone is where the unconsolidated material grades into bedrock. It consists primarily of saprolite and variably weathered bedrock. Particle size ranges from silt and clay to large boulders of un-weathered bedrock. The thickness of this zone depends on the texture and composition of the rock. Together, the regolith and transitional zones are usually less than 100 feet thick in the Piedmont (Daniel, 1987).

The deepest zone is fractured crystalline bedrock. The uppermost part of this zone contains numerous closely spaced fractures. Fracture frequency and size in the bedrock tend to decrease with depth. Generally, very few fractures occur in Piedmont bedrock at depths greater than 400 feet (LeGrand, 1967).

Heath's (1984) concept of a generalized groundwater system for the Piedmont is presented here as the conceptual hydrogeologic model for the subject area. The fundamental components of this system are the regolith, the transitional, and the fractured bedrock zones. The saturated regolith and transitional zones generally provide the bulk of water storage within the Piedmont groundwater system (Heath, 1980). These zones serve as reservoirs supplying water to interconnected fractures within the fractured bedrock zone. Most of the natural flow of the shallow groundwater system occurs in the upper 30 to 50 feet of bedrock where fractures are concentrated, and the overlying saturated transitional zone. The primary porosity of the saturated regolith and transitional zones, which occurs as voids between grains in the soil, sands, saprolite, and weathered rock, can range from 35% to 55% (Daniel and Dahlen, 2002), which allows a large groundwater storage volume. The porosity of the bedrock, however, only occurs in open fractures and typically averages around 0.1% (Heath, 1980). The fractures in bedrock are not usually extensively connected, which tends to limit the area of impact from a groundwater pumping system in fractured rock.

The groundwater flow system in the Piedmont is also directly connected to the surface water system (Harned, 1989). **Figure 3** schematically demonstrates this connection. The direction of shallow groundwater flow is toward streams that act as discharge areas for the groundwater flow system. Inter-stream areas are areas of recharge. Generally, the shape of the water table mimics the topography of the land surface, although with subdued relief, so that surface topography can be used to predict the natural direction of groundwater flow.

Site Geology and Hydrogeology

The proposed Snow Camp Quarry site lies in the Piedmont physiographic province and the eastern edge of the Carolina Slate Belt geologic terrane. The Pine Hill Branch Fault and the South Fork Fault system lie approximately 1.8 miles east southeast and 2.3 miles southeast of the site, respectively (Schmidt, et. al., 2006). The quarry site is in an area bounded to the northwest and southeast by parts of the Major Hill Structural Block (Schmidt, et. al., 2006) and should likely be considered as part of the block. Other, undesignated or un-named structural features are located northwest and southeast of the site.

The geologic map included with the report "Geology and Mineral Deposits of the Snow Camp-Saxapahaw Area, Central North Carolina" (Schmidt, et. al., 2006, U.S. Geological Survey Open-File Report 2006-1259) (**Figures 4/4A**) characterizes the bedrock at the site as a part of the Reedy Branch Tuff. Tuff is defined as an igneous rock consisting of volcanic ejecta (as ash/cinder) that has consolidated in to solid crystalline rock. The Reedy Branch Tuff is typically a crystal-rich rhyolite and dacite tuff which has under-gone greenschist facies metamorphosis. It is remarkably uniform in both texture and composition. Where near the intermediate to felsic volcanic complex, the younger Reedy Branch Tuff is less altered and less deformed than the underlying rock. It is everywhere metamorphosed in the greenschist facies (Schmidt, et. al., 2006).

The tuff consists of plagioclase and quartz crystals set in a fine grained matrix of muscovite, biotite, chlorite, epidote, and other secondary minerals formed during greenschist-facies metamorphism and by later hydrothermal alteration. Sericitization is abundant in the Reedy Branch Tuff and strong hydrothermal alteration has been mapped in the northern portion of the proposed quarry property (**Figure 4/4A**) (Schmidt, et. al., 2006). SCPI reports that the regolith zone overlying the fractured bedrock was between 0 and 15 feet thick in the boreholes drilled on-site and an inspection of core from the site confirms the site mineralogy and weathering to a depth of about 12 feet below land surface (bls).

The source of most of the groundwater to the proposed quarry would be from water filled fractures in regolith and the upper portions of the bedrock. The width and frequency of fractures in bedrock decrease with depth. Although it is likely that more water producing fractures will be encountered at shallower rather than deeper parts of the future quarry, water producing fractures could be present down to the total proposed depth of the quarry which is anticipated to eventually be over 200 feet bls.

The Alamance County GIS department indicates that is no county water supply system. Water supplies to residences are from individual wells or shared wells in certain subdivisions. Well construction information for the area was limited and was obtained from two sources: a USGS database detailing groundwater monitoring in the central Piedmont and the NC Division of Water Resources – Source Water Assessment Program (SWAP) Report for the Alamance-Orange Water System (a small private water system). Two wells listed in the USGS database were reviewed for this report. The wells were generally constructed in the transition zone from regolith to fractured rock with casing from land surface to competent rock, with screen intervals below the water table. The wells range in depth from 40 feet to 50 feet. Well yields were not reported. The two nearby wells listed in the SWAP report were both completed as open hole wells in fractured rock. The wells were constructed with the casing grouted into the top of the bedrock and extended to depths of 540 feet (Well #2) and 525 feet (Well #3). Yields were reported at 140 gpm and 127 gpm, respectively. The higher yields of these wells can likely be attributed to the storage capacity of the deep wellbore.

Fracture Trace/Lineament Analysis

As noted above, groundwater flow in fractured bedrock is restricted to interconnected fractures. These fractures or joint sets frequently exhibit on land surface as connected drainage patterns as the fractures provide a mechanism for deeper weathering of the rock and create a zone of weakness that is more easily eroded by surface water. Fracture traces visible on aerial photographs and topographic maps are natural linear drainage, soil-tonal, and topographic alignment are probably the surface manifestation of underlying zones of fracture concentration. This method of well-site location using mapped linear features was first described by Lattman and Parizek (1964). Fracture trace or lineament mapping was defined by O' Leary and others (1976) as "extended mappable linear or curvilinear features of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures or faults in the subsurface". These features are mappable at various scales, from local to continental, and can be utilized in mineral, oil and gas, and groundwater exploration studies.

Lineaments mapped in the area of the proposed Snow Camp Quarry generally fall into two categories: fault related and foliation related. The fault related fractures trend roughly parallel to the Pine Hill Branch Fault system and the South Fork Fault system noted above. Both of these fault systems strike approximately 50° northeast (**Figure 4**). Several outcrops of bedrock were identified on the subject property (**Figure 2**) and were measured using a geologic compass app on an iPhone. The fracture strikes ranged between 55° and 65° NE. The fracture dip (a measure of the vertical component of a geologic structure) was steep, ranging between 71° and 79° south/southeast. These measurements were confirmed by the fracture trace analysis performed for the site using connected drainage patterns as depicted on the area topographic map (**Figure 5**). **Table 1** presents the field measurements of the outcrop fracture planes.

The foliation related fractures form along the repetitive layering found in metamorphic rocks. The layers may be as thin as a sheet of paper, or over a meter in thickness. Foliation is common in rocks affected by the regional metamorphism compression typical of areas of tectonic activity. The foliation fractures in the proposed quarry area appear to strike toward the northwest. Due to weathering of the outcrops, no measurable foliation fractures were observed on the property.

The fracture trace analysis gives some indication of the density and connectivity of significant fracturing in the shallow bedrock. The fracture density appears to be low and based on the apparent displacement and cut-off of foliation, the interconnectivity of the fracture sets do not likely extend over significant distances.

Potential for Impact on Groundwater Resources

A detailed hydrogeologic study of the proposed Snow Camp Quarry site has not been performed. However, we assume at this time that the impact to groundwater resources in the proposed quarry area will be similar to impacts experienced near quarries with similar geologic and hydrogeologic conditions.

During the site reconnaissance, water levels were measured in 2 existing, in-active water supply wells on the property near the southern and northern edges of the property (**Figure 2**) (**Table 2**). Construction details or other information about the wells such as total depth, casing depth, and yield were not available due to the assumed age of the wells. The well designated as WSW-1 appears to be a drilled well with an 8" diameter steel casing at land surface located at an old abandoned farmstead. Depth to groundwater in that well was approximately 39 feet bls. The well designated as WSW-2 is a hand dug well with a 4 foot square surface hole and bricked upper portion. This well was located at an abandoned one room school house. There was a drilled well adjacent to the dug well but the wellhead for that was not accessible. The total depth of the dug well was measured at approximately 41 feet below the top of the brick. Depth to water was measured at 29' bls. Water levels alone, without the qualifying well information are of little use to this investigation. However, the drilled water supply wells could likely be converted to monitoring wells and they are located at prime spots for continued long term monitoring of the site.

State permit files were reviewed for two nearby quarries with similar geologic and hydrogeologic conditions (**Table 3**): the Martin Marietta Burlington quarry, located approximately 13 miles north northwest, and the Martin Marietta East Alamance quarry, located approximately 18 miles north. The Burlington quarry has been in operation since 1974 and the East Alamance quarry since 1988. Each quarry has received an NPDES permit from the N.C. Division of Water Resources to discharge water from the quarry pit and no violations have been reported for those permits. The water discharged from the pits is a combination of groundwater and rainwater, however, the majority of water in the pits is rainwater. Based on the average annual rainfall for the Burlington area (http://usclimatedata.com), 1 acre of active quarry pit will receive approximately 3,350 gallons of rainwater per day. As an example, the Burlington quarry is permitted to discharge 340,000 gallons per day. The active mining area is 211 acres, yielding and average daily rainfall of about 700,000 gallons. Evaporation will account for the loss of part of the rainwater in the pit and part of the water is used for dust control and washing the crushed stone. The dust control and wash water seeps back into the ground and is effectively recycled on the property. Reviews of the permits for these quarries indicate that groundwater pumping from the pit is minimal. Records for the East Alamance quarry show that pit water was only discharged to the surface receptor after periods of heavy rainfall and that daily discharge didn't exceed approximately 25,000 gallons per day. Based on this information, it is obvious that the amount of groundwater being pumped is relatively small and the pumping does not significantly impact groundwater conditions away from the quarry pit. Monitoring wells installed at quarries with similar hydrogeologic conditions have shown little to no impact 800 feet from the pit.

We believe that information obtained for these other local quarries represents conditions generally analogous to the proposed Snow Camp Quarry site. At this time, we conclude it is likely that the water table in water supply wells located more than 800 feet away from the proposed quarry pit wall would not be adversely impacted by the quarry operation. Also, based on our experience with other quarry operations, it is likely that groundwater levels will not be influenced in any way by groundwater withdrawals from at a distance of 1,000 feet from the proposed quarry walls. **Figure 6** indicates the 1,000 foot radius around the proposed mining limit and properties within the radius. Based on site observations, it does not appear that any active residential supply wells are within the radius.

Mining in Fractured Crystalline Rock vs. Mining in Coastal Plain Sediments

During previous public hearings for mining permits in similar geologic conditions, this geologist has noted that concerns were voiced about the wide ranging impacts to groundwater and the causation of sinkholes due to mining activities. Since this site is not located in the coastal plain and is not in a limestone terrain, there is a negligible potential for sinkhole formation. The only fractured rock mining related sinkholes in North Carolina that this geologist is aware of occurred over an old, abandoned gold mine in Cabarrus County. Groundwater pumping for golf course irrigation drew the water table down sufficiently to weaken a filled shaft in the old gold mine and the collapse of the shaft created a sinkhole at land surface in the sub-division built adjacent to the golf course. There does not appear to be a similar concern at this site.

The rock type, limestone vs. crystalline rock, is critical to the formation of geological sinkholes. Eastern North Carolina limestone is typically quite porous and is very soluble. Due to these aspects, cavities, and potentially caverns, can form in the limestone as it dissolves in slightly acidic groundwater. As the water table is lowered below the top of the limestone, the soils and sediments overlying the rock can collapse into these cavities, eventually reaching land surface and forming a sinkhole.

The crystalline bedrock of the Piedmont is not soluble and is not likely to form cavities where overlying materials can collapse to form sinkholes. Sinkholes formed in areas underlain by crystalline bedrock are almost invariably due to a break in a water line or storm drain line which causes a washout of the surrounding soils and results in a localized sinkhole. Therefore, we can conclude that sinkholes are extremely unlikely to form due to groundwater drawdowns in crystalline bedrock.

Concerning the wide ranging impact to the local aquifer system, rock mining in the North Carolina Coastal Plain is carried out exclusively in areas underlain by a shallow limestone. The limestone frequently occurs as a confined aquifer as opposed to the unconfined nature of quarries and aquifers in the Piedmont. Alley and others (1999) discuss the significantly different response of confined and unconfined aquifers to pumping before the ground-water system returns to a new equilibrium. Their research has shown that drawdowns in the confined aquifer are always larger than drawdowns in the unconfined aquifer, and that significant measurable, drawdowns occur at much larger distances from the pumping well in the confined aquifer. In their idealized scenario, they determined that the total volume of the cone of depression in the confined aquifer is about 2,000 times larger than the total volume of the cone of depression in the unconfined aquifer for this example of a hypothetical infinite aquifer. Thus, the depth of drawdown and the areal extent of the cone of depression in a confined aquifer are orders of magnitude larger than those in an unconfined aquifer (**Figure 7**) (Alley, et.al., 1999).

Conclusions and Recommendations

Geologists have completed a preliminary hydrogeologic study in the vicinity of the proposed Snow Camp Quarry located between Clark Road and Quackenbush road, approximately 2 miles south of the unincorporated town of Snow Camp in Alamance County, North Carolina. The preliminary investigation is based on information provided by Carolina Geological Services, Inc. and Snow Camp Property Investments to support work in the preliminary permitting process for the proposed quarry. The scope of work primarily included the compilation of existing data and the evaluation of new data and field observations collected during site visits. This report describes the hydrogeology of the area and potential impacts of quarry development on local ground- water resources. Based on this preliminary study, the following conclusions were reached:

The proposed Snow Camp Quarry and any the water supply wells in the area receive their groundwater from interconnected fractures in metamorphic or igneous bedrock. In general, most of these fractures occur in the upper 30 to 50 feet of bedrock, although water-bearing fractures could occur deeper in wells or in the quarry pit walls. The majority of drilled water supply wells in the area will tend to be constructed in fractured bedrock although some shallow wells may be completed in the overlying saprolite. Residential well yields tend to be approximately the same in both rock and sand wells, ranging from 1 to 30 gallons per minute. Local wells reviewed for this report were from a USGS database and the NC Division of Water Resources Report for a local private water system. The USGS database reports the wells were generally constructed in the transition zone from regolith to fractured rock with casing from land surface to competent rock and screen intervals below the water table. The wells were 40 to 50 feet deep and well yields were not reported. The two nearby wells listed in the SWAP report were both completed as open hole wells in fractured rock. The wells were constructed with the casing grouted into the top of the bedrock and extended to depths of 540 feet (Well #2) and 525 feet (Well #3). Yields were reported at 140 gpm and 127 gpm, respectively. These records provide a wide range for area wells. There are currently 2 inactive water supply wells on the subject property. The nearest active water supply well not on the subject property is located more than 1,000 feet from the proposed quarry.

The geological data and literature indicate it is not likely that the water table in residential water supply wells located more than 500 feet away from the proposed Snow Camp Quarry pit wall would be adversely impacted by the quarry operation. Also, it is not likely that groundwater levels will be influenced in any way by groundwater withdrawals at the proposed quarry at a distance of 1,000 feet from the proposed quarry walls. This conclusion is based on a review of available information obtained during this preliminary investigation, including a comparison of conditions at other quarries with similar geologic and hydrogeologic conditions. Comparative information was reviewed from North Carolina Division of Environmental Quality files for the Burlington quarry and East Alamance quarry. A detailed hydrogeologic study of the proposed Snow Camp Quarry area has not been performed. However, it is likely that the impact to groundwater resources in the proposed Snow Camp Quarry area will be similar to impacts experienced at these nearby quarries with similar geologic and hydrogeologic conditions.

A limited fracture trace analysis was performed for the area surrounding the subject site and determined the following: the fracture trace analysis gives some indication of the density and connectivity of significant fracturing in the shallow bedrock. The fracture density appears to be low and based on the apparent displacement and cut-off of foliation, the interconnectivity of the fracture sets does not likely extend over distances. Therefore, one can expect little to no impact to groundwater resources beyond the property boundaries. The existing water supply wells located on the property appear to be ideally situated for conversion to monitoring wells and beginning a groundwater monitoring program.

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Author Qualifications: Robert Christian (Chris) Reinhardt, P.G.

EXPERIENCE SUMMARY

Mr. Reinhardt has more than 30 years of experience in geology and hydrogeology and has an understanding of complex environmental and regulatory issues as well as strong technical management qualifications with years of progressive and varied project experience. Mr. Reinhardt has worked in 22 US states, performing hundreds of Phase I and Phase II Environmental Site Assessments, UST removals, Comprehensive Site Assessments, Hazardous Waste Site Assessments, and Remedial Feasibility Studies. He has worked in karst terraines, coastal plain sediments, and fractured crystalline rock, has participated in stream and wetlands restoration projects, mine permitting, and drilling projects for numerous municipal water supply systems. He was instrumental in drafting the NC Guidelines for the Investigation and Remediation of Soils and Groundwater at Petroleum Contaminated Sites. His work has given him varied experience in mining and asphalt/concrete facilities, military sites, residential and commercial development, petroleum and agricultural chemical sites, dry cleaners, and heavy industrial sites, plus geologic support for geotechnical investigations.

Mr. Reinhardt trained dozens of field personnel for the environmental assessment of 292 square miles of agricultural property acquired by the South Florida Water Management District for the "River of Grass" restoration project. His experience also includes: managing the closure of a PCB contaminated site in Colorado; the investigation of environmental and hydrogeologic liabilities at about 50 active and in-active mines and greenfield sites in multiple states; investigation and remediation of groundwater incidents at multiple asphalt plant sites; environmental and geologic evaluation and borehole logging for caisson/foundation drilling at a Hybrid Energy Center built on a re-claimed coal mine in southwest Virginia; geologic and hydrogeologic design for a greenfield landfill site in western NC; and managing a municipal solid waste landfill closure and methane gas investigation at a former landfill site in central NC.

LICENSE

NC Professional Geologist No. 1044

EDUCATION

Graduate Studies - Hydrogeology – East Carolina University - 1987/1988
BS Geology – Appalachian State University - 1986

TRAINING/CERTIFICATIONS

40 Hour HAZWOPER Training plus 8 Hour Annual HAZWOPER Refreshers
24 Hour OSHA HAZWOPER Supervisor Training
Registered Site Manager, NCDWM REC Program
New Miner Training–MSHA/NCDOL Certification Part 46 and Part 48
USEPA Course - Hazardous Waste Site Sampling
USEPA Course – Protection of Public Water Supplies from Groundwater Contamination
E^3 Course – Groundwater Flow and Characterization in Fractured Rock
AEG/AIPG Course – Groundwater in Crystalline Rock

Tables

Table 1: Outcrop Fracture Measurements
Proposed Snow Camp Quarry
Snow Camp, Alamance County, North Carolina

Outcrop#	Latitude	Longitude	Strike	Dip
OC-1 (Fracture)	N35.870409°	W79.419137°	N55˚E	78˚S
OC-2 (Fracture)	N35.869779°	W79.417383°	N62˚E	72˚SE
OC-3 (Fracture)	N35.872246°	W79.414307°	N65˚E	71˚SE

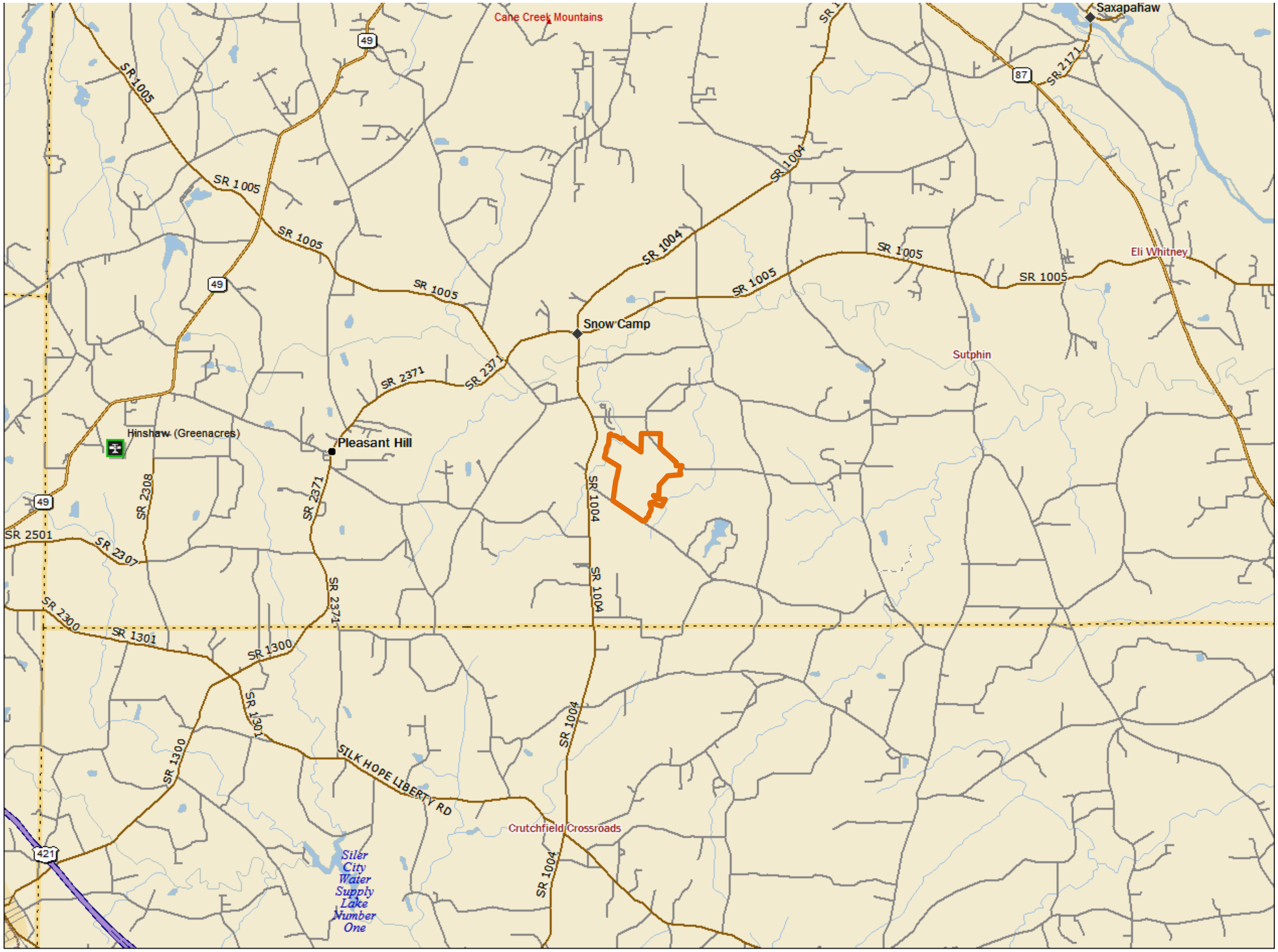
Table 2: Well and Borehole Measurements
Proposed Snow Camp Quarry
Snow Camp, Alamance County, North Carolina

Well #	Latitude	Longitude	Approx. Land Surface Elevation	Approx. Depth to Water	Casing Stick-Up (Above Land Surface)	Water Level (Below Land Surface)
WSW-1	N35.864687°	W79.420557°	642’	40’	1’	39’
WSW-2	N35.873155°	W79.415771°	633’	31’	2’	29’

Table 3: Alamance County - Active Quarry Mining Permits Reviewed
Proposed Snow Camp Quarry
Snow Camp, Alamance County, North Carolina

Permit #	Permittee Business Name	Location Name	River Basin	Original Issue Date	Select Address, City, State, Zip	Permit Revised Date	Mine Status	Permit Acres	Quadrangle Name	Latitude Measure	Longitude Measure
01-02	Martin Marietta Materials, Inc.	Burlington Quarry	Cape Fear	04/24/1974	P O Box 30013 Raleigh, NC 27622	07/15/2013	Active	350	Gibsonville	36.05833	-79.5094
01-08	Martin Marietta Materials, Inc.	East Alamance Quarry	Cape Fear	03/04/1988	P O Box 30013 Raleigh, NC 27622	07/15/2013	Active	611	Burlington NE	36.1341	-79.3607

Figures

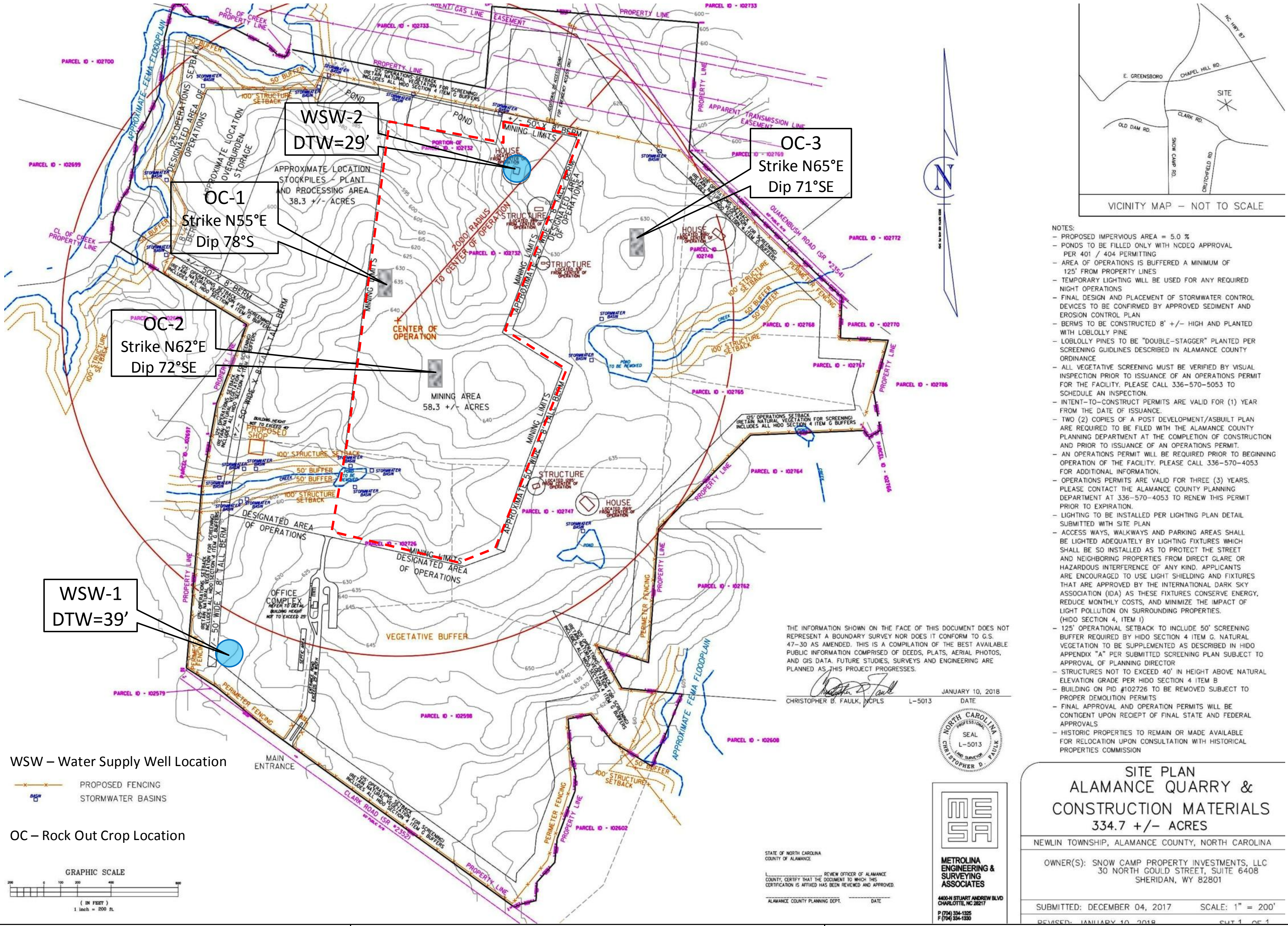


MN (8.7° W)

0 ½ 1 1½ 2 2½ mi

Data Zoom 11-0

Parcel Boundary		Approximate Site Location Proposed Snow Camp Quarry		Robert Christian Reinhardt, PG Geology • Hydrogeology • Environmental Science 7620 Mine Valley Road, Raleigh, NC 27615 rein82@bellsouth.net
Scale: As Shown	Base Map from DeLorme StreetAtlas	RCR Project No. 18-M-14-02	**Figure 1**	



Property Boundary Mining Limit	**Site Plan with Well and Out Crop Locations** **Proposed Snow Camp Quarry**
Scale: As Shown	Plan Provided By Carolina Geological Services, Inc.
RCR Project No. 18-M-14-02	**Figure 2**

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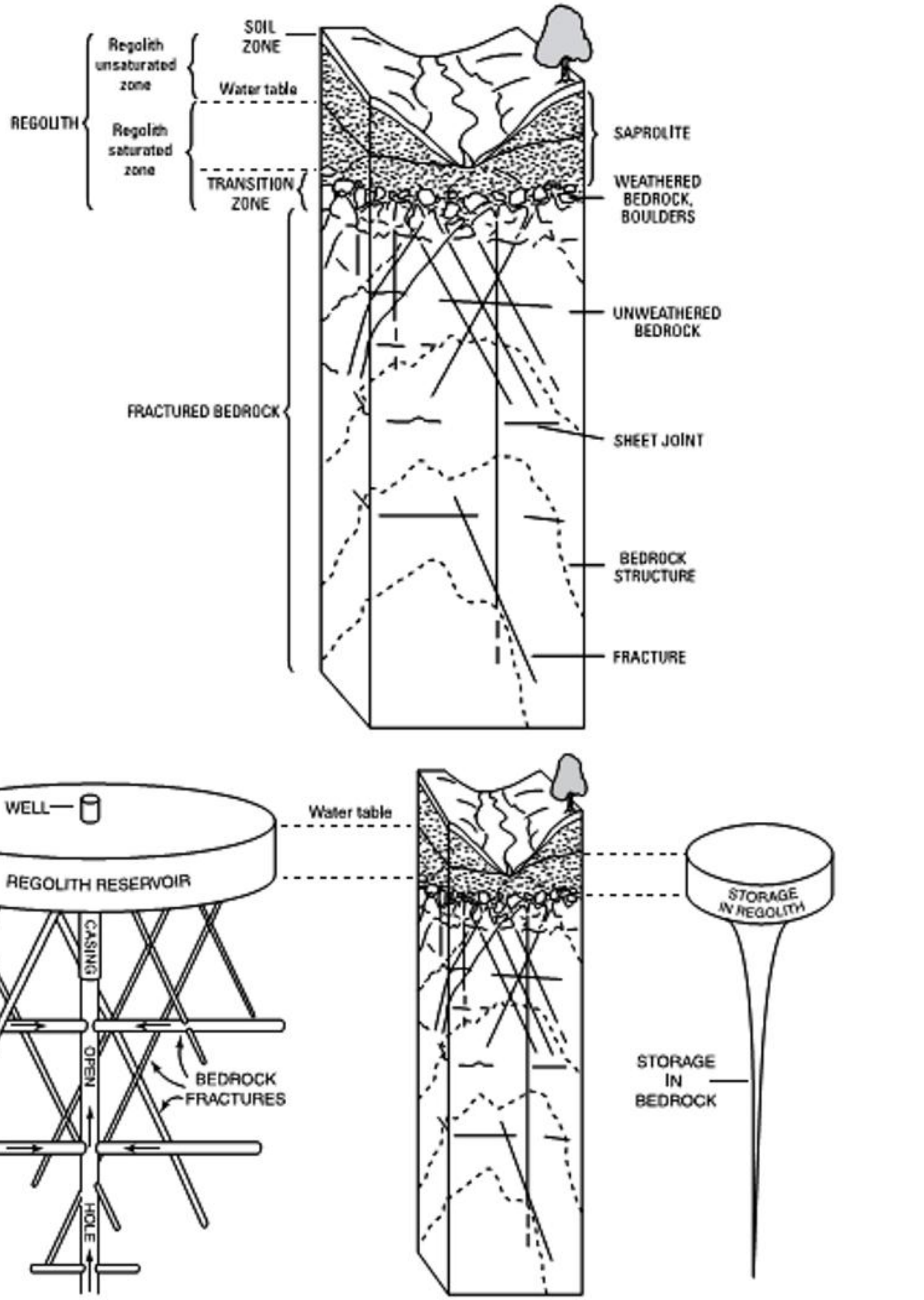

No Scale	Conceptual Groundwater Flow in Fractured Crystalline Rock in the Piedmont of North Carolina	
Source: Daniel, C.C. III and Dahlen, P.R., 2002, U.S. Geological Survey Water-Resources Investigations Report 02–4105	RCR Project No.: 18-M-14-02	**Figure 3**

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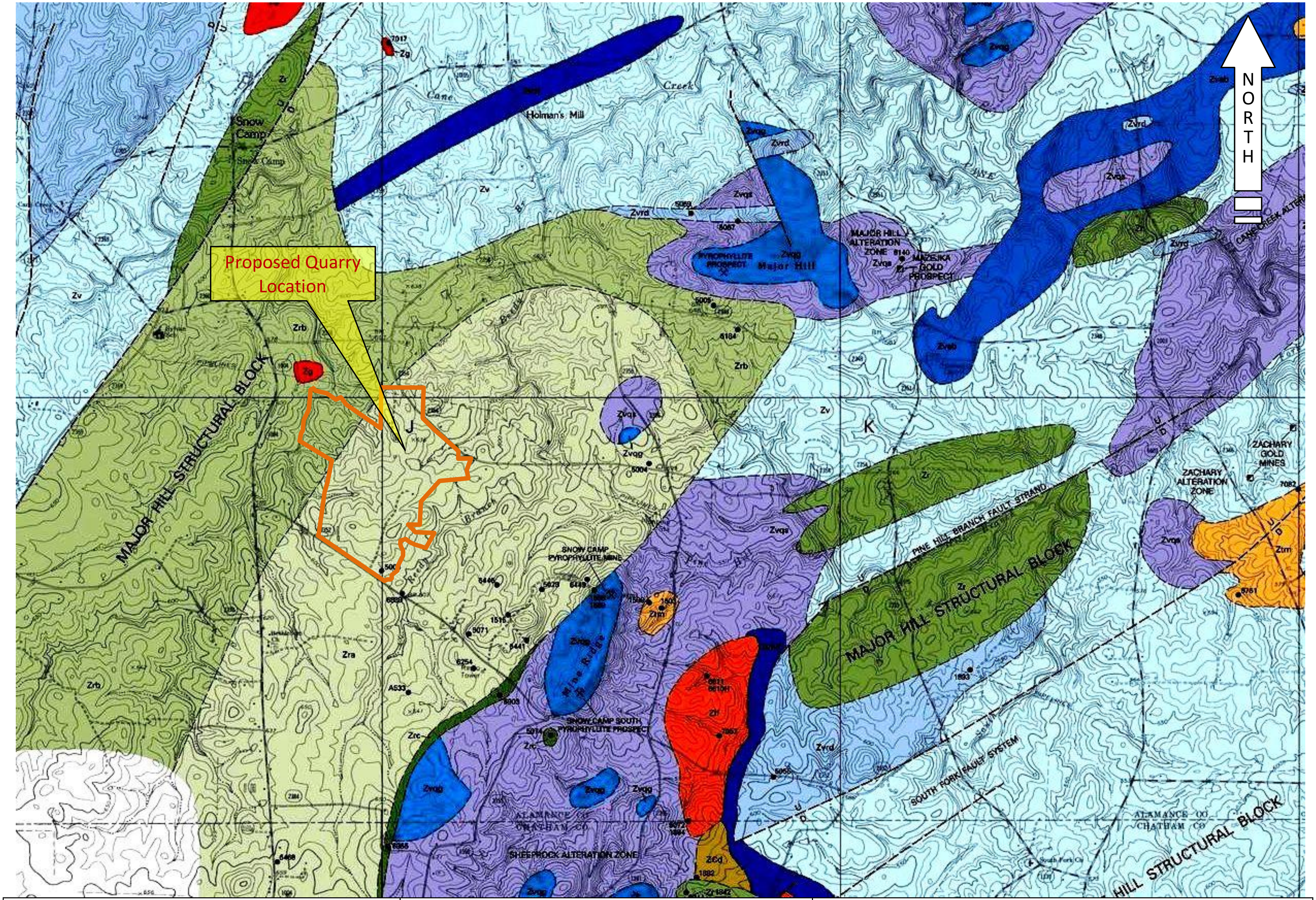

Parcel Boundary		**Area Geologic Map** **Proposed Snow Camp Quarry**	
Scale: 1" = 3,460'	U.S. Geological Survey Open-File Report 2006-1259	RCR Project No. 18-M-14-02	**Figure 4**

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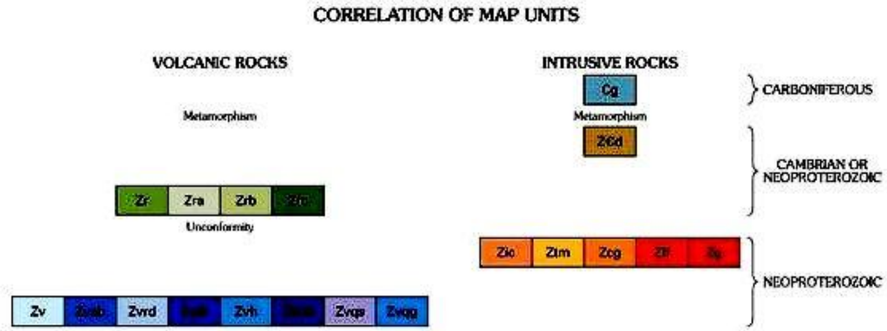
CORRELATION OF MAP UNITS



EXPLANATION

- - - **Contact**—Position inferred from scattered outcrops or soil types

— — **Fault**—Position inferred from topographic features, juxtaposition of unrelated rock types, observed shear zones, lineaments noted on Landsat and side-looking radar images, and boundaries of mapped soils. U, upthrown side; D, downthrown side

Mine or prospect shaft

Pit or quarry

1515 ● **Location of sample mentioned in text and collected for analysis**—Analytical results given in tables 1–7

DESCRIPTION OF MAP UNITS

VOLCANIC ROCKS

Zr — **Reedy Branch Tuff (Neoproterozoic)**—Rhyodacitic and dacitic tuff containing abundant euhedral to subhedral plagioclase crystals and lesser quartz phenocrysts in a very fine grained matrix of muscovite, biotite, chlorite, epidote, calcite, ilmenite, and anatase; commonly contains small inclusions of dark, fine-grained rock, most of which are smaller than 0.4 in (1 cm); a few may be as much as 6 in (15 cm) long; some are angular and some are rounded

Zra — Reedy Branch Tuff that is slightly to moderately altered to quartz-sericite

Zrb — Reedy Branch Tuff that is strongly altered to quartz-sericite and, locally, is strongly sheared

A discontinuous subunit up to a few feet (meters) thick at the base of the Reedy Branch Tuff that contains abundant rounded clasts of a variety of volcanic rocks in a crystal-rich matrix; interpreted to be a debris flow unconformably overlying the older strata. Locally consists of two or more clast-rich layers separated by layers of crystal-rich tuff

Intermediate to felsic volcanic complex (Neoproterozoic)—Mixed basaltic to rhyolitic tuff and coarse pyroclastic rocks, in part fragment rich; contains a few flows and volcaniclastic rocks. The entire assemblage is assumed to be older than the Reedy Branch Tuff. The regional correlation by Offield with the Aaron(?) Formation and the Hyco Formation of Harris (1982) is tentative

Zv — Tuffs, coarse pyroclastic rocks, and lesser flows and volcaniclastic rocks—Mixed lithic types and outcrop spacing precluded further subdivision in mapping. Where possible, individual rock types were mapped separately, but no internal stratigraphic sequence was recognized

Andesitic or basaltic rocks—Few outcrops observed but a long narrow area of mafic rock is suggested by Tirzah- and Efland-type soils (Kaster, 1960)

Zvrd — Siliceous, partly flow-banded rhyolites and dacites—Probably constitute most of the volcanic rocks in the Cane Creek Mountains; elsewhere linear outcrop areas no more than 3 mi (5 km) long. These isolated areas are interpreted to be underlain by flows, domes, or stubby lenses. Flow banding is present in about half of the outcrops examined. These rocks include crystal-rich lapilli tuffs that contain some lithic fragments, tuff that contains compacted and deformed shards, and lapilli tuffs in which fine devitrified glass has preserved patches of flow layering, some layers contain microspherulites

Probable debris flows east of Snow Camp community—Several thin beds of coarse conglomerate, perhaps lahars, contain diverse volcanic cobbles, separated by layers of dacitic and andesitic tuff

Hornfels adjacent to the Lindley Farms Quartz Monzonite in sectors J and N

Zvqs — Quartz-sericite-paragonite rock—Light-gray to grayish-green, altered intermediate to felsic volcanic complex. Original lithic textures generally remain recognizable. Commonly contains a trace to several percent pyrite. Also includes potassically altered rocks and epidote-rich altered rocks within and near plutons. Outer edges grade into volcanic rocks without hydrothermal alteration; inner contacts with siliceous core zone generally abrupt

Zvqp — Siliceous core-zone rocks—Generally gray to white intermediate to felsic rocks that are intensely altered to very siliceous quartz granofels and associated pods of pyrophyllite-andalusite-pyrite rock. Accessory minerals include chloritoid, topaz, magnetite, hematite, tourmaline, and, less commonly, lazulite. Quartz-healed breccias common; original lithic textures generally faint or totally obliterated

INTRUSIVE ROCKS

Cg — **Unmetamorphosed granitoid rock (Carboniferous)**—Small areas of granite, dacite, and rhyodacite, quartz-rich and potassium-poor, light-colored and medium-grained, and molybdenum-bearing greisenlike muscovite quartz-epidote-sulfide rock. Some areas are strongly deuterically or hydrothermally altered. Rounded and partly embayed quartz phenocrysts are common; traces of potassium feldspar occur as replacements on microfractures. Propylitic alteration was incomplete and parts of the plagioclase phenocrysts retain their delicate oscillatory zones. Unmapped apophyses of unmetamorphosed granitoid rocks have intruded metamorphosed plutonic rocks in sectors C and D, and the northern halves of sectors G and H, such as at sites 6258, 6571, 6682, and 6707 (fig. 2, sectors D and H). The unmetamorphosed porphyritic hornblende quartz monzonite at site 6610H (fig. 2, sector J) was identified largely on the basis of float fragments ranging in size from cobbles to large boulders

Zcd — **Metamorphosed porphyritic dacite stock (Cambrian? or Neoproterozoic)**—Rock commonly contains plagioclase phenocrysts in a matrix of plagioclase and lesser quartz; no potassium feldspar was recognized. Epidote-rich rock is a locally abundant alteration phase. No outcrops were found; distribution was inferred from common float cobbles and a local area of quartz-rich soil. Probably associated epidote-rich veins cut nearby Reedy Branch Tuff suggesting that these rocks are probably younger than that unit

Zic — **Quartz-diorite-hornfels-volcanic rock injection complexes (Neoproterozoic)**—Volcanic rock hornfels cut by multiple apophyses of fine-grained plutonic rock and variously textured porphyry; intrusive component may equal or exceed hornfels and volcanic rock. Excellent exposures of fine-grained quartz diorite in small bodies that have injected roof rock hornfels and masses, separated by hornfels screens, are present for 1.25 mi (2 km) along the banks of Cane Creek in sector H

Zim — **Intrusive rocks, medium-grained, hypidiomorphic granular to porphyritic (Neoproterozoic)**—Generally silicified granite, rhyolite, dacite, rhyodacite, trachyte, quartz monzonite, quartz monzodiorite, quartz monzogabbro, granodiorite, and quartz diorite. In addition to primary quartz, plagioclase, and potassium feldspar, metamorphic minerals include epidote, biotite, muscovite, and chlorite; graphic and myrmekitic aggregates of quartz and feldspar are common in some bodies. A few small stocks underwent intense quartz-sericite and local potassic alteration; the latter is indicated by hydrothermal biotite. Hornblende developed locally during metamorphism at one site. Abundant wall-rock inclusions and variations in composition indicate that the rocks were modified by assimilation of andesitic material from the walls. Some mapped contacts were inferred from the extent of Appling, Cecil, and Helena soils (Kaster, 1960) with which these rocks correlate well

Zcg — **Granite intrusions in the Cane Creek Mountains (Neoproterozoic?)**—Three areas of light-pink to light-gray, medium-fine-grained to porphyritic, plagioclase-rich granophyric granite that probably merge at depth into a shallow plutonic body; their margins grade into porphyries having aplitic groundmasses. Feldspar, predominantly sodic plagioclase, is dominant; potassium feldspar is mostly incorporated in the common myrmekite, perthite, and irregular granophyric and graphic intergrowths. Epidote and complexly metamorphosed biotite are present. We think that these granitoid inclusions are older than the Reedy Branch Tuff

Lindley Farms Quartz Monzonite (Neoproterozoic)—Medium- to coarse-grained rock consists of light-gray quartz and feldspar and about 20 percent dark minerals in grain-sized aggregates that appear black in hand specimen, granophyric textures common; widely contaminated by the assimilation of mafic wall rocks. Also includes granite porphyry and quartz monzogabbro. Thoroughly saussuritized; the greenschist- to amphibolite-facies transition is indicated by green amphibole in newly formed mafic mineral aggregates. Limits of areas underlain by this rock cannot be inferred from the soil type

Gabbroic stocks (Neoproterozoic)—Small bodies of gabbro, quartz monzogabbro, hornblende quartz monzogabbro, diorite, and hornblende gneiss, having chilled margins and zones of assimilated wall rocks. Metamorphic hornblende, biotite, and newly formed potassium feldspar are common; metamorphism here was in amphibolite facies. Cuneiform quartz and myrmekite are present. Outcrop data were collected from areas near Foust Mine and other bodies close to the Snow Camp fault; and the further distribution of the rock was inferred from the presence of characteristic Davidson, Iredell, and Mecklenburg soils (Kaster, 1960)

Schmidt, Robert G., Gumiel, Pablo, and Payás, Alba, 2006, Geology and Mineral Deposits of the Snow Camp-Saxapahaw Area, Central North Carolina: U.S. Geological Survey Open-File Report 2006-1259

Geologic Map Legend
Proposed Snow Camp Quarry

RCR Project No. 18-M-14-02 | **Figure 4A**

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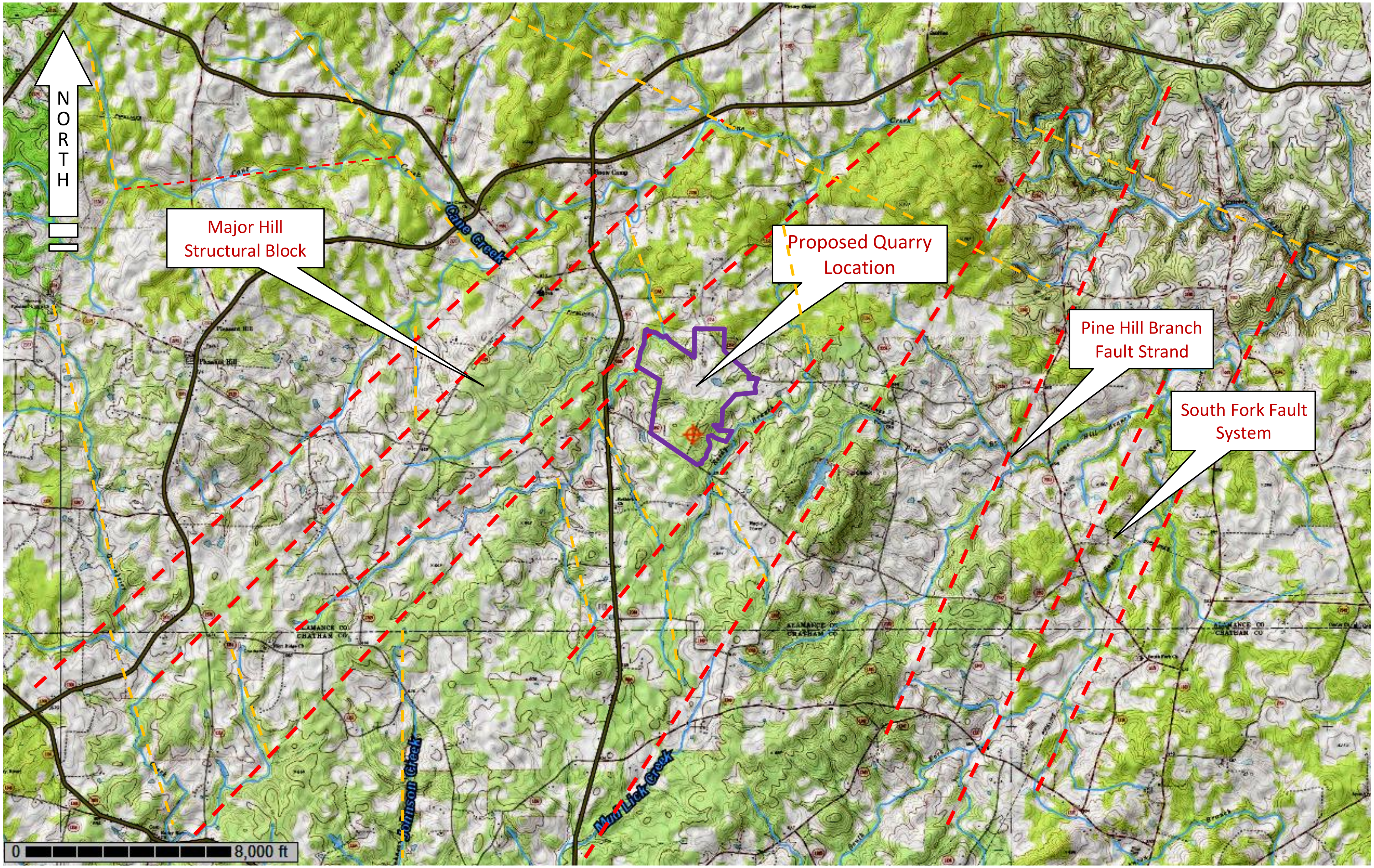
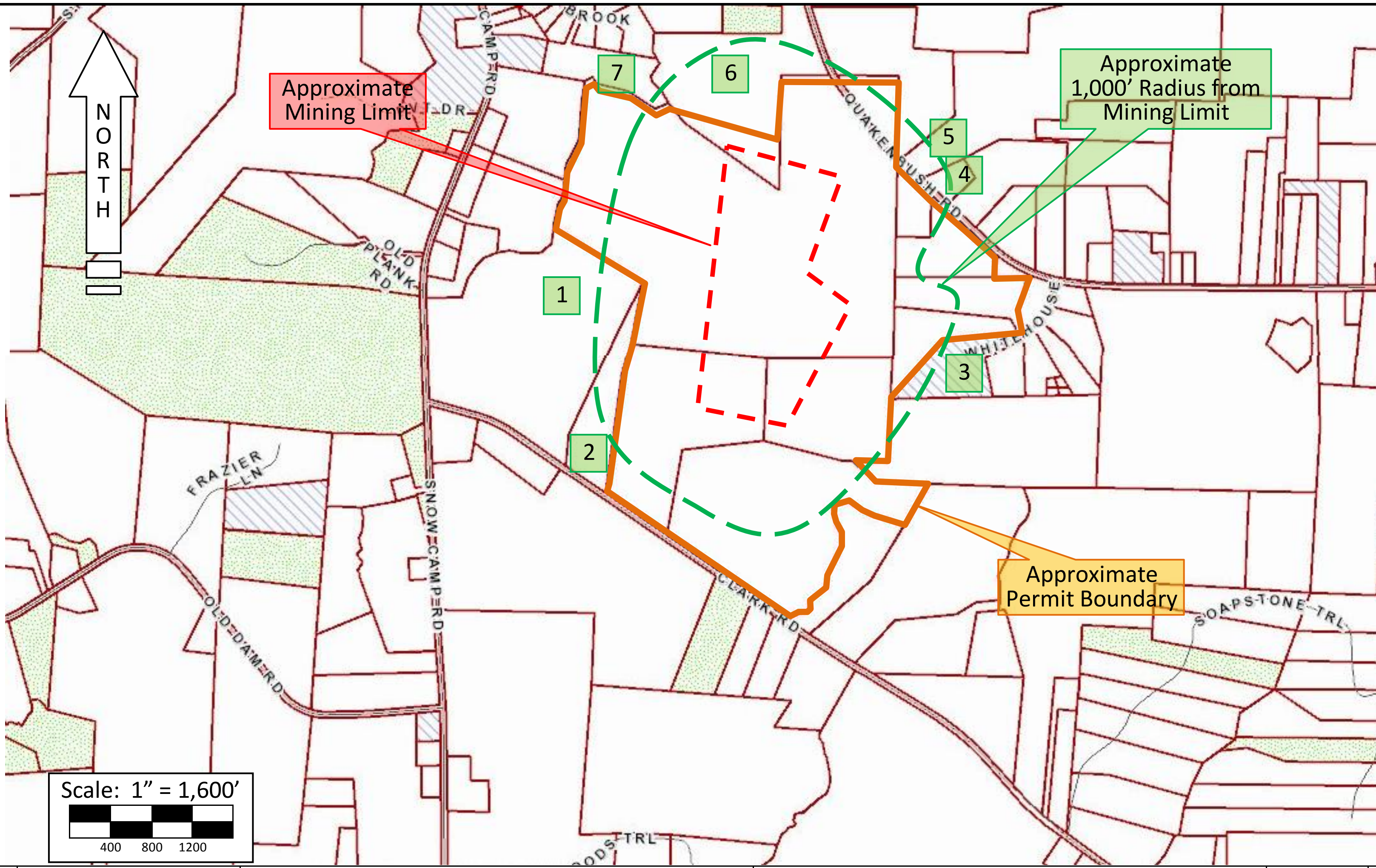


Parcel Boundary Fault Related Fractures Foliation Related Fractures	**Lineament-Fracture Trace Approximation** **Proposed Snow Camp Quarry**		**Robert Christian Reinhardt, PG** Geology • Hydrogeology • Environmental Science 7620 Mine Valley Road, Raleigh, NC 27615 rein82@bellsouth.net
Scale: As Shown	USGS 7.5' Topo Quad Snow Camp	RCR Project No. 18-M-14-02	**Figure 5**



	Parcel ID	Parcel Address	Owner Name	Owner Address	Acres	Well/Septic*
1	102698	CLARK RD	MILLS, STEPHEN D, WENDIE ANN EGGLESTON	PO BOX 520, SNOW CAMP, NC 27349	67.715	No Record
2	102697	262 CLARK RD	JACKSON, NORMAN F JR	PO BOX 740, SNOW CAMP, NC 27349	7.285	No Record
3	102764	9065 WHITEHOUSE CT	MULROONEY, TIMOTHY J, MULROONEY, CELESTE M	9065 WHITEHOUSE CT, SNOW CAMP, NC 27349	10.5	Y / N
4	102769	1732 QUAKENBUSH RD	LEE, BRIAN J & CARRIE T	1732 QUAKENBUSH RD, SNOW CAMP, NC 27349	2.33	No Record
5	102799	1720 QUAKENBUSH RD	CAUSEY, PAMELA A REVOC TRUST	6144 SMITHWOOD RD, LIBERTY, NC 27298	68.92	No Record
6	102733	1503 QUAKENBUSH RD	STUART, DANNY RAY	1503 QUAKENBUSH RD, SNOW CAMP, NC 27349	66	No Record
7	102715	7561 SOUTHBROOK LN	FAIN, MICHAEL T & DANIELLE M	PO BOX 667, SNOW CAMP, NC 27349	9.65	No Record

Parcel Boundary

Properties Within 1,000 Feet Of Proposed Mining Limit
Proposed Snow Camp Quarry

Scale: As Shown

* Source: Alamance County GIS Database

RCR Project No. 18-M-14-02

Figure 6

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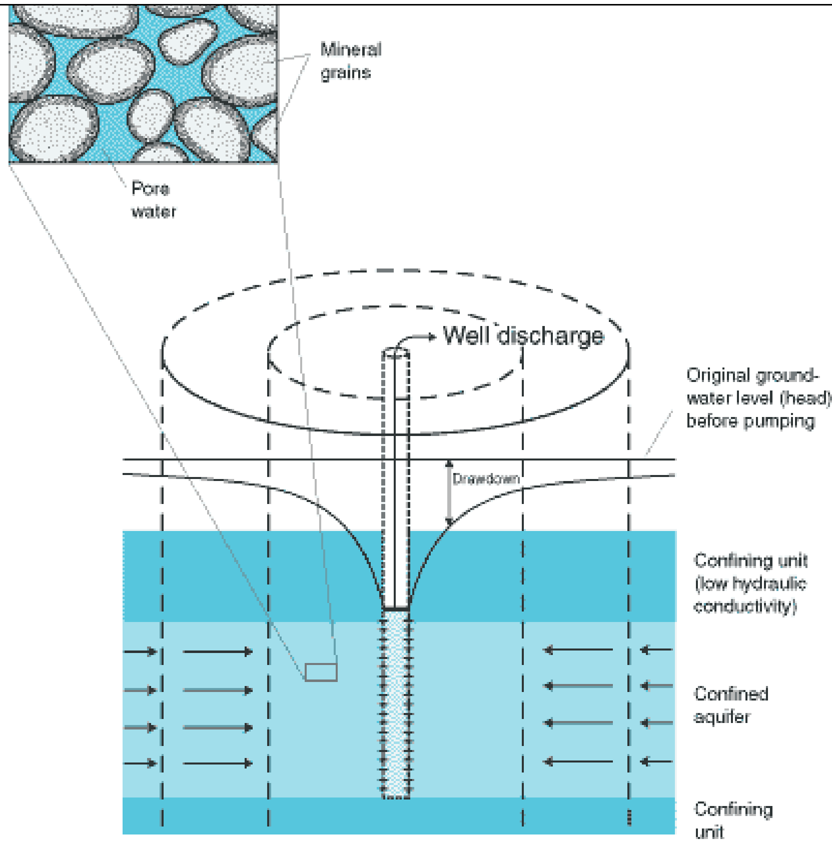
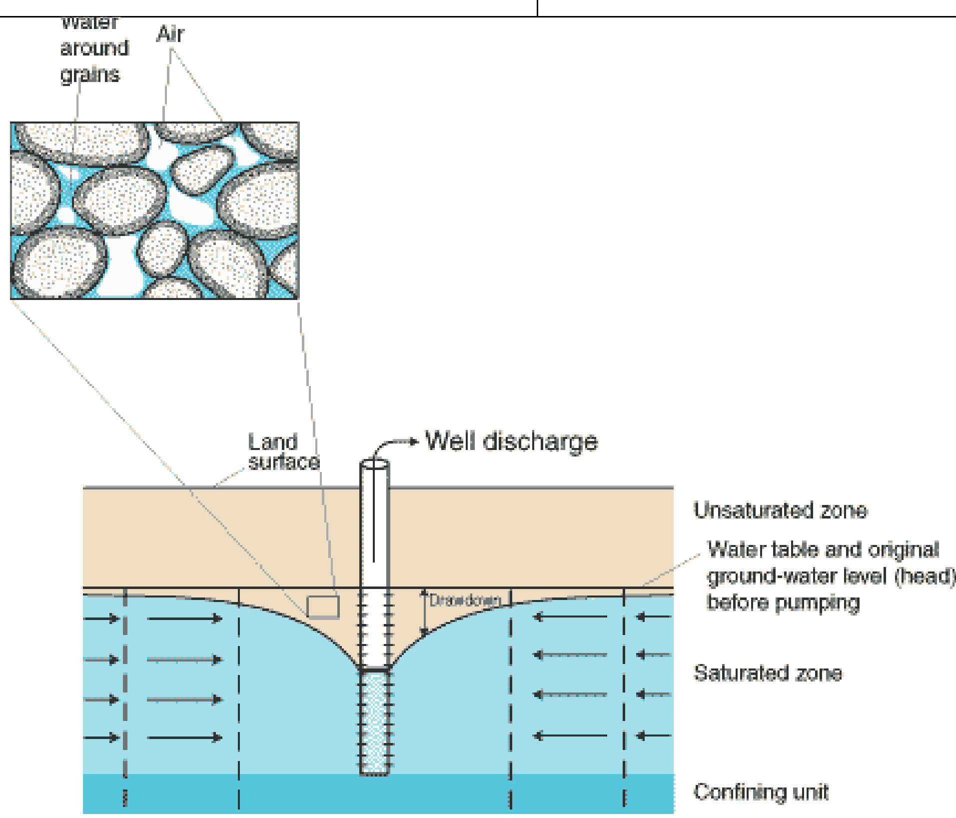


Pumping a single well in an idealized confined aquifer. Confined aquifers remain completely saturated during pumping by wells (saturated thickness of aquifer remains unchanged)

Pumping a single well in an idealized unconfined aquifer. Dewatering occurs in cone of depression of unconfined aquifers during pumping by wells (saturated thickness of aquifer decreases).



No Scale	**Conceptual Groundwater Flow Pumping From Confined vs Unconfined Aquifers**	
Source: Alley, W.M., T.E. Reilly, O.L. Franke, 1999: Sustainability of Groundwater Resources: U.S. Geological Survey Circular 1186	RCR Project No.: 18-M-14-02	**Figure 7**

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