

Raritan Confining Unit Field Identification Protocol

(November 16, 2012 MODIFIED version)

Introduction

This is a modification of the standardized protocol developed in February 2012 (ARCADIS 2012) for field identification of the Raritan Confining Unit (RCU) (i.e., the hydrogeologic designation for the unnamed clay member(s) of the Upper Cretaceous-age Raritan Formation on Long Island, New York). This protocol is intended as guidance for field geologists/scientists during oversight of drilling for selecting split-spoon sampling and Hydropunch groundwater sampling intervals and the depth to terminate vertical profile borings drilled along the Northrop Grumman Site southern boundary, and incorporates data from VPBs completed since issuance of the February 2012 RCU protocol, specifically Northrop Grumman VPBs VP3-1, and VP-73R/VP-33 drilled and sampled along the Northrop Grumman western and southern boundaries, respectively, and Navy VPBs VP-134, VP-135, and VP-136, drilled and sampled along the southern boundary of the former Naval Weapons Industrial Reserve Plant (NWIRP). This modified protocol was specifically developed to take into account the data developed by the Navy from the above mentioned three VPBs. These recent VPBs drilled by the Navy revealed three distinct clay layers at approximately 600, 700, and 800 feet below land surface (bls) as well as intervening sand units underlying the 600 and 700 ft clays. This modified protocol will allow the same three clays to be documented in VP-74 if they exist at this location and soil and groundwater samples to be taken from the intervening sand units. However, the Navy data indicate no site-related VOC detections below the 600 ft clay. If similar results are obtained from VP-74 then any future VPBs that may be drilled by Northrop Grumman will use the original (February 2012) and not this modified protocol. While this protocol was specifically prepared for field staff overseeing the drilling and sampling of deep boreholes that are part of the On-site Containment (ONCT) System Hydraulic Effectiveness Evaluation program performed for Northrop Grumman Systems Corporation, in Bethpage, New York (Northrop Grumman), this protocol will be useful to other investigators in confidently identifying this unit. As described in the February 2012 protocol, this update is intended to be a flexible field guide that can be adjusted to fit site-specific field conditions based on the geologists/scientists experience. This protocol stresses the need to adequately identify: 1) the RCU and in so doing confirm that the transmissive Magothy aquifer and any substantial sandy layers in the Raritan Formation, through which advective transport of impacted groundwater could occur, has been fully penetrated and 2) in the case of the ONCT system evaluation program, the vertical extent of volatile organic compound (VOC) contamination in groundwater. The RCU is generally hard, solid clay of substantial thickness that severely restricts the exchange of groundwater (and by extension impacted groundwater) between the Magothy aquifer and the deeper Lloyd aquifer. Across Long Island, the large head differences measured between these two aquifers (at well clusters that screen both aquifers) is testament to the significant character of the RCU as a local and regional confining unit. For the purpose of this ONCT investigation, the RCU can be considered the bottom of the aquifer system.

Raritan Confining Unit and Magothy Aquifer Lithology and Depositional Environments

The RCU and overlying Magothy aquifer are the “hydrogeologic equivalents” of the Raritan Formation clay member and Matawan Group – Magothy Formation, undifferentiated, respectively. They are both Upper Cretaceous age units whose depositional origin is considered to be continental in nature (generally thought to be an environment of streams and coalescing deltas). The deposits in each unit include gravel, sand, silt, and clay. The differentiation between the units is not easily made based on mineral or sand type identification methods (both units generally contain quartzose sands with pyrite, iron oxide concretions and lignite common) but rather is more readily made from a hydrogeologic perspective based on grain size relative to the percent occurrence of that grain size within the unit. That is, a clay lense sample from the Magothy aquifer may look extremely similar to a clay sample from the Raritan clay, however, from an overall percent occurrence of clay encountered within the two units, clay is significantly more abundant in the RCU (with extensive lateral continuity). Color of deposits may also be used to assist in unit identification (gray clay and pink/red clay from Magothy and Raritan, respectively) however; it is by no means definitive. A more common and reasonably reliable field method of differentiation is to observe the transition of deposits encountered in the vertical sequence. Although the Magothy is characterized primarily by fine to medium sand, silt, and clay lenses, typically the basal zone exhibits a marked increase in grain size to the extent that the basal Magothy horizon is identified by its coarse sand, gravel, to even cobble size deposits. These coarse deposits typically rest directly on the erosional or non-depositional unconformity that separates the two units. The unconformity marks a vast change in the depositional environment, from very high energy (coarse deposits) to much lower energy levels (clay). The transition from the basal gravel zone is typically abrupt and the clay of the Raritan is encountered directly beneath the gravel zone however, the basal gravel zone has been noted to not always be present. Encountering this sequence of deposits, used in conjunction with all other available information and interpretations has commonly been used to mark this hydrologic unit boundary across Long Island.

Procedures for Implementing the Protocol

The following are procedures for identification and characterization of the RCU and a framework for field staff to make decisions. As described in the preceding section, the mineralogy, grain size, color, etc. of the Magothy aquifer and RCU are not easily distinguishable when comparing single samples from each unit. More importantly for the purposes of these investigations, the existence, thickness, and continuity of clays encountered is most important rather than the ability to differentiate the deposits based on age or geologic name. The focus should be on identifying the transition through the coarse basal Magothy horizon into the fine clay deposits of the Raritan. Most certainly, geophysical logs of such deep borings are invaluable in also identifying a sharp transition zone and correlating lateral features.

1. Review applicable literature

a. Review Smolensky and others (1989)-“Hydrologic Framework of Long Island, New York” and specifically Sheet 2 of 3- the map showing the “Altitude of the Upper Surface of the Raritan Confining Unit” to obtain an initial indication of the expected altitude of the top of the RCU at a planned drilling location(s) by locating the proposed borehole(s) to be drilled on this map. For

convenience in the field during drilling oversight, use a topographic map of the area or a nearby surveyed elevation to convert the expected RCU altitude to a depth in feet below land surface.

b. Review Buxton and others (1989)-“Hydrogeologic Correlations for Selected Wells on Long Island, New York-A data base with retrieval program” which is the companion publication to the Smolensky report referenced above and contains the basic data on which that report was based. Look in the Buxton report for wells near the planned drilling location(s) to obtain more site specific information to refine the expected depth to the RCU.

c. Review data from Vertical Profile Borings VP-73R and VP-33, which were completed in January and March 2012, respectively as part of the Phase 1 ONCT System Hydraulic Effectiveness Evaluation program, and which reached and penetrated into the RCU. The borings were advanced approximately 28 and 22 ft below the top of the unit, and the RCU deposits were characterized as light gray to red solid clay. Immediately overlying the clay was a horizon of sub-round to round quartz pebbles. Gamma logs confirmed the abrupt change in deposit type. Also review data from VP-3-1 which also penetrated the RCU but at a greater depth (over 80 feet) than the RCU was reached at VP-73R and VP-33. At VP-3-1, the clay was dark gray and the horizon of pebbles was not present immediately above the RCU.

d. Review data from other recently completed borings that have penetrated the RCU in the general area. Of particular interest are recent Navy VPBs VP-134 (westernmost VPB), VP-135, and VP-136 (easternmost VPB), completed in mid-2012. These VPBs were completed north of the ONCT Hydraulic Effectiveness Evaluation area and penetrated a sequence of three clay units separated by sandy sequences. The first clay was encountered between 635 and 636 ft bls and ranges between 11 and 22 ft in thickness. This clay thins to the east (“600 ft clay”) and does not appear to be present at VP-136 although a 5-ft thick clay was found at a depth of 565 feet and another clay 5-ft thick was found at a depth of 678 feet. The second, more substantial clay was encountered between 699 and 720 ft bls and ranges between 46 and 57 ft in thickness, (“700 ft clay”). The third clay was only fully penetrated in VPB VP-135, and the depth to the clay ranges between 813 and 820 ft bls and its thickness ranges from 37 ft in VP-135 to greater than 59 ft in VP-136 (“800 ft clay”). Generally, these clays are characterized as competent, dry and dark gray in color. Based on the depths and thicknesses of the clays, it is expected that these units will be encountered at somewhat deeper depths along the Northrop Grumman southern boundary. Sandy sequences were noted at the VPBs as follows:

VPB ID	Thickness of Sand Sequence below “600 ft clay”	Thickness of Sand Sequence below “700 ft clay”
VP-134	54 ft	62 ft
VP-135	53 ft	58 ft
VP-136	37 ft *	47 ft

* Assuming 683 ft is concluded to represent the bottom of the “600 ft” clay sequence at VP-136.

Based on data provided by Navy, VOCs were not detected at depths greater than 598 ft bls, 478 ft bls, and 581 ft bls in VP-134, VP-135, and VP-136, respectively.

2. Drilling and split-spoon sampling

a. Communicate the objective of the borehole to the driller before commencing drilling and maintain communication throughout the borehole drilling to obtain his observations on material being penetrated by the drill bit. Ask him to tell you when he is drilling in sand or gravel and when he believes the borehole is penetrating clay or silt. Periodically note the drilling fluid pressure (if using a fluid based drilling technique and the rig has such a gage) as pressure increases may indicate penetration of a low permeability layer such as silt or clay.

b. While drilling through the Magothy aquifer, examine and describe split-spoon samples (according to ARCADIS' Standard Operating Procedure for Soils) for evidence of the RCU based on the descriptions given above for these units. If drilling is carried out using drilling fluid, note any color changes in the fluid that might indicate that the RCU has been reached. Generally, the Magothy tends to be gray with some white, but the RCU tends to be red, brownish-red, and pink. The red to brownish-red RCU frequently contains very thin white layers, which collectively can produce a pinkish color in the drilling fluid once the RCU has been penetrated.

c. Be aware that the basal zone of the Magothy aquifer is typified by coarse sand and gravel, and small cobbles have even been encountered in this horizon. The basal Magothy coarse zone may be tens of feet thick and at some locations may be up to 75 to 100 feet thick however, it is not always present. This horizon is reflective of a high energy environment and many times will stand in stark contrast to the fine sediment of the low energy environment of the underlying RCU.

d. Once the borehole reaches a depth close (30 feet above) to the anticipated depth of the surface of the "600 ft clay" based on the literature and borings described above, increase the split-spoon sampling frequency to every 5 feet. Along the Northrop Grumman site southern boundary, it is anticipated that the RCU will be encountered between 630 and 650 ft bls, so 5 ft interval split spoon samples should commence at 600 ft bls. After the first spoon sample suggestive of the RCU (see above section "**Raritan Confining Unit and Magothy Aquifer Lithology and Depositional Environments**" for RCU descriptions) is observed, continue split-spoon sampling at 5 ft intervals through the "600 ft" and "700 ft" clays as wells as intervening sand sequences, until the "800 ft clay" is encountered. Split spoon sampling will then continue at 5 foot intervals with the goal of penetrating a minimum of 20 feet of the "800 ft" clay. If the material penetrated in the "800 ft" clay is predominantly clay characteristic of the RCU, the boring will be terminated. In addition, at any time during drilling through the clay should the driller convey that sand has been encountered, drilling will be suspended and a decision will be made with the office staff as to whether an additional split spoon(s) will be collected. **It is very important to note any significant changes in grain size (particularly zones of potentially higher transmissivity) at the base of the Magothy aquifer and in the intervening sands between the clay sequences noted above.**

e. If during split-spoon sampling it is no longer possible to advance the split spoon (i.e., refusal is reached-decided in the field with driller input) when the borehole has penetrated into the “800 ft” clay, then the driller will be instructed to complete steps 2f through 3b. If the geophysical logging indicates that the basal 20 ft of the borehole is predominately clay then the borehole can be terminated. However, if the geophysical logging indicates that the interval is not predominately clay then a decision should be made, with office project management staff, to either attempt to conduct additional drilling/split-spoon sampling or terminate the borehole. If the borehole has only reached the “600 ft” or “700 ft” clay then drilling should continue and split spoon sampling should be attempted again after drilling an additional 10 ft.

f. Once the drilling has been terminated, if using a fluid based drilling system, request the driller to slowly re-drill the borehole portions opposite each clay member encountered that is characteristic of the RCU to ensure that any swelling of the clay into the borehole is overcome and the borehole remains open to its full drilled diameter. Also, ask the driller to continue to circulate the drilling fluid until all entrained sediment has reached the fluid pit and settled out to the extent practical to help ensure that the borehole remains open to its full drilled depth so that geophysical logging can be effectively carried out.

3. Geophysical logging

a. Have the driller pull the rods from the borehole and then proceed with geophysical logging of the borehole (gamma ray log). However, if there are concerns about borehole stability the gamma ray log may be run inside the rods.

b. Review the split-spoon geologic descriptions and compare to the gamma ray log to confirm that the RCU has been reached and is predominately clay and, if confirmed, then drilling can be considered terminated.

4. VOC groundwater sampling

a. The modified Hydropunch sampler should be used to collect groundwater samples for VOC and field parameters (pH, specific conductance, temperature) analysis. Hydropunch samples will not be attempted from the clay units described above. Hydropunch samples will be collected following each split spoon from the basal Magothy zone at 5 ft intervals, beginning 30 ft above the expected top of the RCU (see **2d** above) and at 10 ft intervals from intervening sandy zones between the three major clay members described above. Should split spoon samples from intervening sandy zones between the clay members listed above indicate a zone of substantially higher transmissivity (e.g., coarse sands or gravels), then an additional Hydropunch sample will be collected from that interval.

Water samples collected as part of this protocol will be analyzed for VOCs by a fixed location laboratory on a 24-hour turnaround basis.