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Recommendations for Construction of a new Water-Supply Well for the Cades Cove Visitor Center, Great Smoky Mountains National Park

The existing water-supply well at the Cades Cove Visitor Center is of indeterminate age. The well produces sand when it is pumped; a clear indication that the casing or screen has failed. Additionally, water pumped from the well has a high iron concentration. A new well is needed to provide water for the visitor center. Peak demand for NPS facilities in this area is about 12,000 gpd. The general location for the new well is shown on Figure 1.

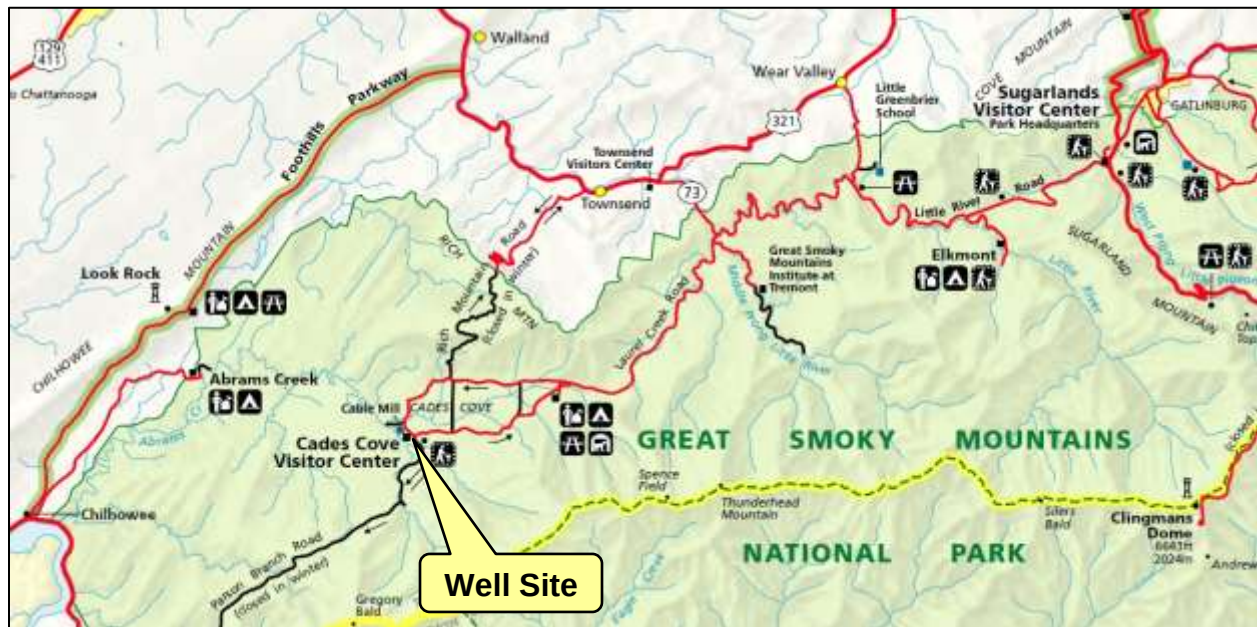


Figure 1. General location for a new well at Cades Cove, Great Smoky Mountains National Park.

Hydrogeology

Geologically, Cades Cove is a type of valley known as a limestone window. The area was covered by older, Precambrian rocks that were thrust over the younger formations. Subsequent erosion of the older Precambrian sandstone, exposed the younger Paleozoic limestone beneath. More erosion-resistant formations, such as the Cades sandstone which underlies Rich Mountain to the north and the Elkmont and Thunderhead sandstones which form the Smokies crest to the south surround the cove, leaving it as a relatively isolated valley. As with neighboring limestone windows, the weathering of the limestone produced deep, fertile soil, making Cades Cove attractive to early farmers.

The geologic map (Figure 2) and cross-section (Figure 3) from Neuman and Nelson (1965) help to illustrate the relationships of bedrock formations and the formation of Cades Cove. The cross-section line passes from the northwest to the southeast, through the middle of the cove.

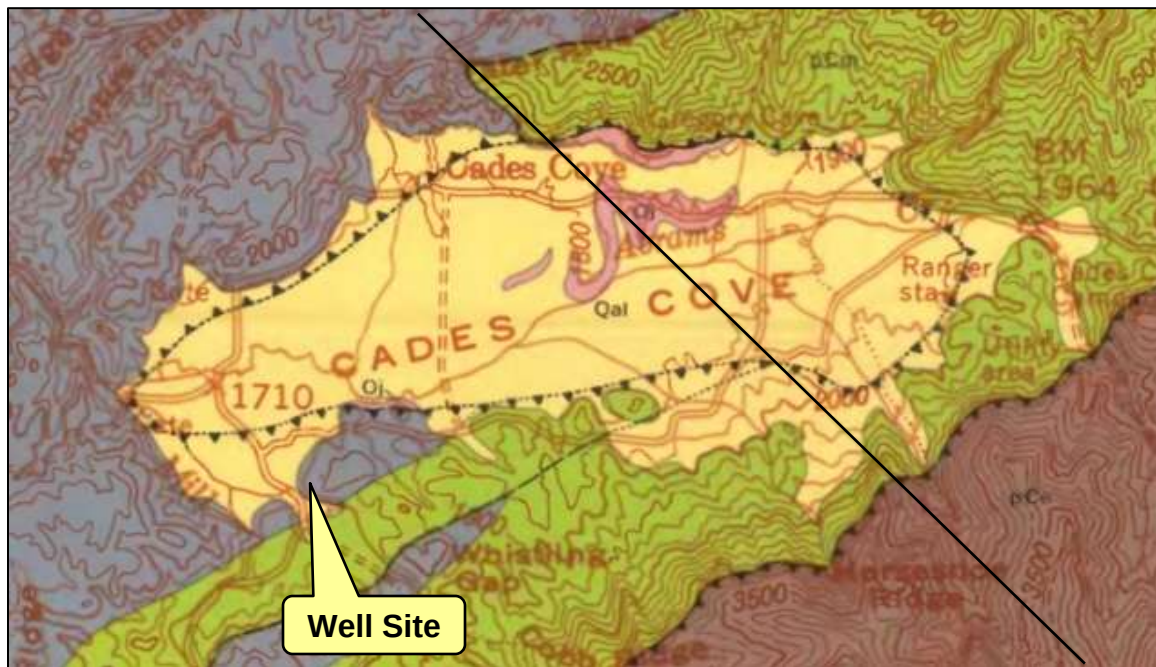


Figure 2. Geologic map of Cades Cove, from Plate 2, (Neuman and Nelson , 1965)

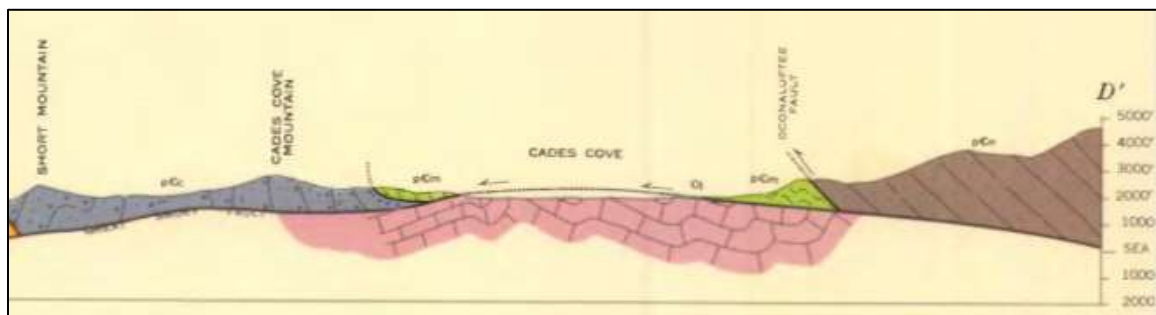


Figure 3. Geologic cross-section through Cades Cove, from Plate 2 (Neuman and Nelson, 1965).

Cades Cove is underlain by the Jonesboro Limestone formation. Overlying the limestone is alluvium derived by erosion of the surrounding upland areas and carried into the valley by streamflow. The alluvium forms a blanket of sediment that may range from many tens to hundreds of feet thick over the limestone. The northwest and west sides of the cove are bounded by bedrock of the Cades Sandstone formation. The northeast and southeast sides of the cove are bounded by bedrock of the Metcalf Phyllite formation.

At the site of the existing well, we would expect drilling to encounter maybe a few tens of feet of unconsolidated sediment, then sandstone for some distance, then crushed rock associated with the fault zone, then limestone. Unfortunately, we have not found a geologic log for the existing well to provide information regarding the depth to these features.

Since we do not have a log for the existing well, we don't know which geologic formation(s) are the source(s) of water for the well. Sandstone is often a source of water, and given that the current well is producing sand, may be exposed in the well. The thrust fault may be a zone of crushed rock which could be a permeable zone and yield groundwater to a well. The underlying limestone formation could be another source of groundwater.

Neuman and Nelson (1965, Plate 6) provide a structure contour map for the Great Smoky fault surface (Figure 4). Their map shows the fault zone at the well site to be at an altitude of about 1700 feet. This estimate might easily be off by 100 feet as was observed during the drilling of the well at the campground at the east end of Cades Cove.

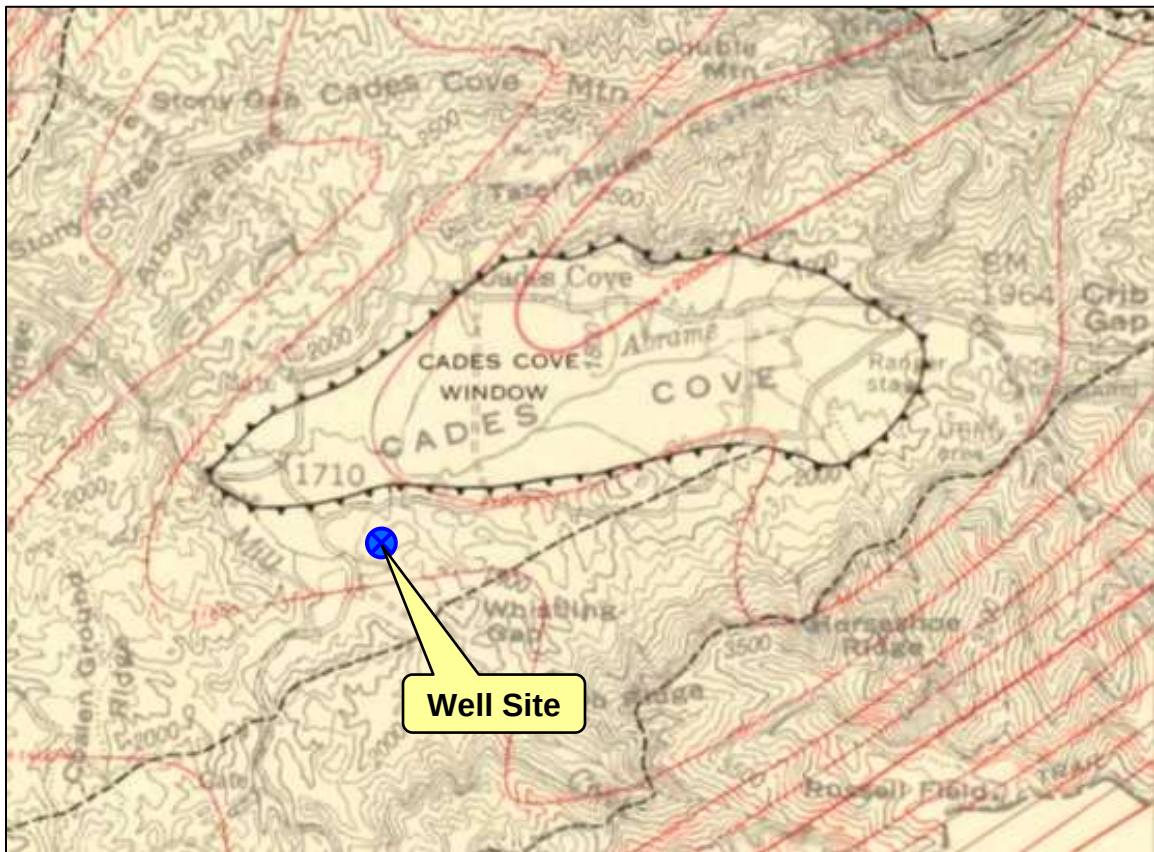


Figure 4. Structure contour map of the Great Smoky fault surface. (Neuman and Nelson, 1965)

Previous test drilling

Three test holes were drilled in the Cable Mill area in July 1971 (Figure 5). Drilling and testing were under the supervision of William McMaster (USGS letter report).

Test Hole No. 1 penetrated 10 feet of overburden and 218 feet of sandstone and phyllite. The yield was about 5 gpm. The hole was abandoned and backfilled.

Test Hole No. 2 was drilled to a depth of 300 feet through yellow-red clay without reaching bedrock. It was plugged and abandoned.

Test Hole No. 3 was drilled to a depth of 200 feet through yellow-red clay without reaching bedrock. It was plugged and abandoned.

I have no record or information for the drilling of the existing well. It is reportedly 220 feet deep.

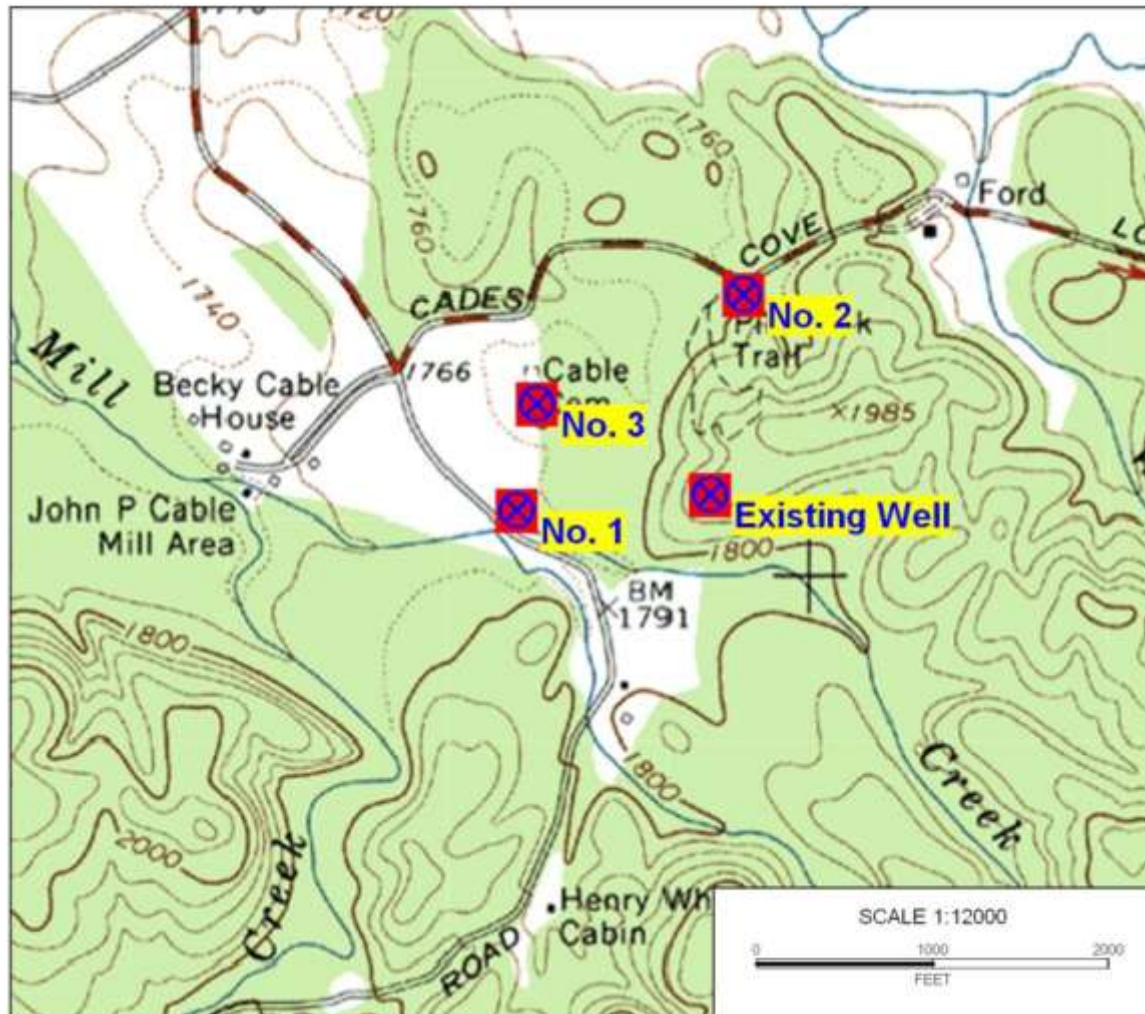


Figure 5. Locations of test holes drilled in 1971 and the current water-supply well.

Analysis and Recommendations

More recent mapping of the Cades Cove area was conducted by Southworth and others (1999). A copy of their map was accessed on the internet on July 8, 2011.

<http://geology.er.usgs.gov/eespteam/smoky/gisData/pdf/cades.pdf>

The map has some minor errors in labeling map units and the author has been informed of those errors. The map helps explain the results of previous test drilling in the area. A small part of that map is shown in Figure 6.

The three test holes drilled in 1971 (labeled No. 1-3) were drilled into alluvial and colluvial debris terrace deposits. These deposits are composed of clay, silt, sand, gravel, and cobbles that form aprons or fans of eroded material from the surrounding bedrock highs out into the valley. The depth to the top of the limestone formation underlying these deposits is unknown. It is a

little surprising that test holes drilled to 200-300 feet did not encounter limestone. Nevertheless, the drilling has shown a thick layer of low permeability sediments in these areas.

The existing well is at the base of a hill that has been mapped as an outcrop of Cades Sandstone (Zc). The well probably penetrates a few meters, or tens of meters, of overburden and then passes into sandstone. The depth to limestone underlying the sandstone is unknown.

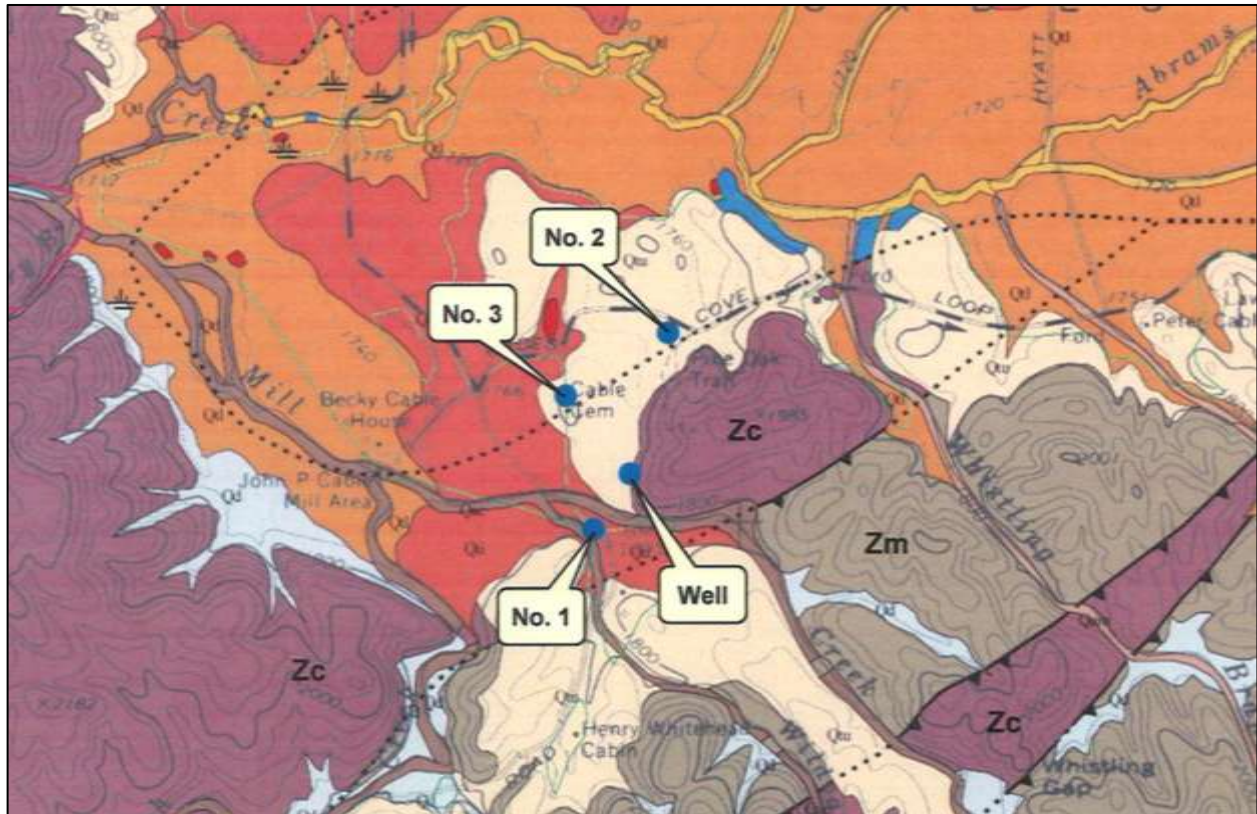


Figure 6. Geologic map of the Cable Mill area. (Southworth, 1999)

Figure 7 shows the locations of test holes and the existing well on a 3-D GoogleEarth map. Test Hole No. 1 is near the base of a bedrock outcrop hill. It encountered bedrock at a depth of 10 feet. Test Hole No. 3 is out in the valley and only encountered overburden for its entire depth of 200 feet. Test Hole No. 2 reportedly encountered only overburden for its entire 300-foot depth. Apparently the thickness of the terrace deposits at this location exceeds 300 feet.

I believe that I can see the existing storage tank at the base of the hill to the east of the open field. The trace of a road to the well and storage tank can also be seen. The hill is a bedrock outcrop of Cades Sandstone. The well drilled at the base of the hill likely penetrates a few tens of feet of overburden and then sandstone for some distance. The structure contour map of the Great Smoky fault surface predicts the fault zone would be at an altitude of 1700 feet in this area, or about 100 feet below ground surface. But that's a highly speculative prediction and the actual depth could easily be another 100 feet or more.



Figure 7. 3-D GoogleEarth projection showing the location of test holes and the well near the Cades Cove Visitor Center.

Test drilling in the valley has shown that the valley is filled with at least a couple hundred feet of overburden in this part of Cades Cove. The additional depth that would need to be drilled to encounter the underlying limestone bedrock is unknown. Estimating the depth to the bedrock surface using the structure contour map of the Great Smoky fault surface clearly underestimates the depth to bedrock (reference to the letter report for the construction of the well at Cades Cove campground).

I recommend drilling the new well in the same general area as the existing well. In addition to all of the infrastructure considerations, the hydrogeology at this location is as favorable as anywhere in the area. We also have the advantage of knowing that a well at this location will encounter an adequate supply of groundwater. The new well could be drilled deeper to obtain water from the fault zone or the underlying limestone formation. Obtaining water from another, deeper aquifer might alleviate the high iron concentration problems that occur from the existing well. A total depth of 350-400 feet should be sufficient to achieve these goals.

If a new well is drilled deeper to obtain water from the fault zone or the underlying limestone formation, then casing could be cemented in place through the entirety of the overlying sandstone and overburden which currently provide water having a high iron concentration. There is a possibility that the zones of poor-quality groundwater could be isolated from contributing groundwater to the new well.

The existing well produces sand when it is pumped. If we decide to complete the new well in the same aquifer (i.e., approximately the same depth), then we should at least construct the new well

in a manner that will prevent sand from entering. This can easily be accomplished by selecting well screen or slotted well casing with openings that are smaller than the sand being produced, or to select a combination of well screen and filter pack that will prevent sand from entering the new well.

As always, the design and construction of the well should include input from the local well drillers regarding construction practices common to the area.

References

Neuman, Robert B. and Willis H. Nelson, 1965, *Geology of the Western Great Smoky Mountains, Tennessee*, U.S. Geological Survey Professional Paper 349-D, 81 pp.

Southworth, Scott, Peter Cirico, and Trevor Putbrese, 1999, *Geologic map of parts of the Cades Cove and Calderwood quadrangles, Tennessee and North Carolina, Great Smoky Mountains National Park*, U.S. Geological Survey Open-File Report 99-175.

Completion of a water supply well at Cades Cove

It would appear that there is plenty of water available from the water-bearing zone at 403-409 feet. However, we also want to be able to have access to the water from the zone at around 290 feet. We want to exclude shallow groundwater as it might be poorer quality. I also note the driller's comment regarding a "soft spot" at 245 feet, thinking that might be a problem area, we will design the well to have cement grout in that area.

We propose to complete the well with 10 feet of "Johnson" well screen from 400-410 feet. Graded sand will be placed in the annular space between the outside of the screen and casing up to about 280 feet to allow any water from the 290 foot level to migrate down through the graded sand and enter the well through the screen. The annular space from land surface to 280 feet will be filled with cement grout to seal off any poor quality groundwater from the shallow aquifers and prevent surface water from migrating down into the well.

The well screen should have 0.050" openings (commonly referred to as No. 50 slot). It should be stainless steel vee-wire wrapped screen as shown in the photos (commonly referred to as Johnson well screen, but also made by other manufacturers). Slotted well screen is not an acceptable substitute.



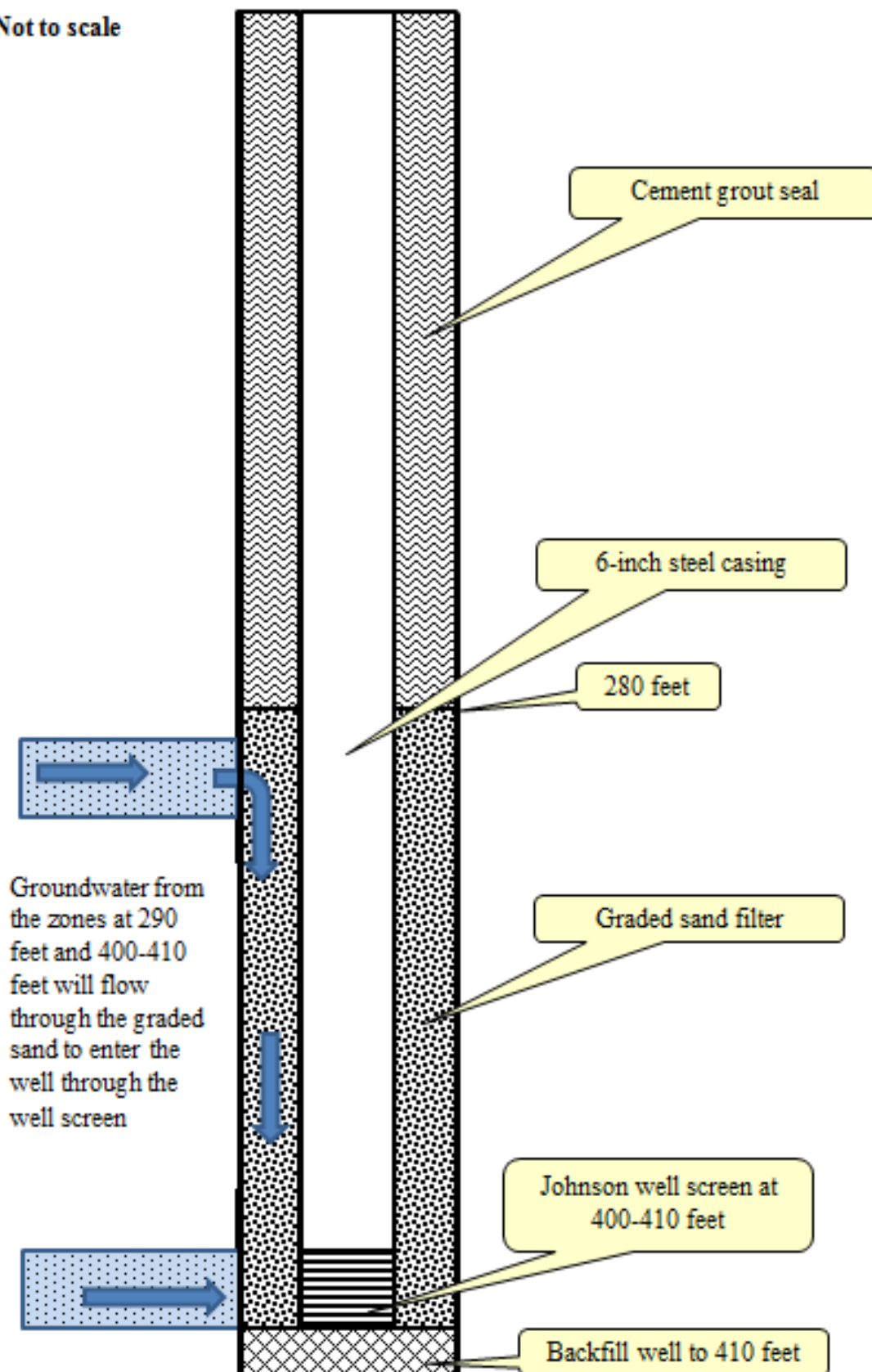
Ten feet of six-inch well screen with No. 50 slot openings is rated to pass 230 gpm.

A diagram of the well design/construction is attached. The well should be completed as follows;

1. Backfill the well with drill cuttings or pea gravel to a depth of 410 feet.
2. Install the well screen and casing. The screen needs to have a casing centralizer at the bottom and above the screen to hold the screen in the middle of the borehole and allow the sand filter to completely surround the screen. Centralizers should be at 398 and 410 feet. Additional centralizers will be needed along the casing string but the number and location is not as critical as for the well screen area.

3. Install the graded sand filter into the annular space between the borehole and the outside of the well screen and casing to a depth of about 280 feet below ground surface. The graded sand should be large enough that it won't pass through the well screen, but small enough to filter sand or silt that may be present in the groundwater or aquifers. In Colorado, I would spec a "6-9" sand, which is readily available in 100 lb bags. The 6-9 designation means that the grains are small enough to pass through a #6 screen, but too large to pass through a #9 screen, or generally in the range of 0.08-0.12 inches.
4. The annular space from 280 feet up to ground surface will be filled with cement grout, using a tremie pipe to insure that the grout is pumped in and fills the space from the bottom up.

Not to scale





TENNESSEE WATER WELL DRILLERS REPORT
DEPARTMENT OF ENVIRONMENT & CONSERVATION
THIS REPORT TO BE SUBMITTED BY DRILLER WITHIN 30 DAYS
AFTER COMPLETION OF DRILLING WATER WELL WITH REQUIRED FEE
TO: DIRECTOR, DIVISION OF WATER SUPPLY, 401 CHURCH ST.
L&C TOWER 6TH FLOOR, NASHVILLE, TENNESSEE 37243-1549

OFFICE USE ONLY

Well No. _____
Date Rec'd: _____
Check # _____
Amount Rec'd: _____
Receipt # _____ Cd# _____

PLEASE PRINT

(1) WELL CONTRACTOR Firm Name <u>Clearwater Drilling Co.</u> Lic. No. <u>609</u> Rig. Operator <u>Tom Morrow</u> Driller Tag# <u>D0097387</u>		(9) WELL OWNER Name _____ FIRST _____ LAST _____ or Company <u>Great Smoky Mountains National Park</u> Address <u>107 Park Headquarters Road</u> City <u>Catlinburg</u> State <u>TN</u> Zip <u>37738</u> Phone # _____																																
(2) WELL LOCATION County <u>Blount</u> Driller Map No. _____ (W) (X) (Y) (Z) ☐ ☐ ☐ ☐ or NUMBER LETTER Latitude: <u>35</u> <u>35</u> <u>070</u> Longitude <u>83</u> <u>50</u> <u>210</u> DEG MIN SEC DEG MIN SEC Well Address <u>10050 Campground Road</u> City <u>Townsend</u> Zip <u>37882</u> Miles _____ (N) (E) (S) (W) of _____ LANDMARK		(10) PROPOSED USE OF WELL Residential ☐ Commercial ☐ Industrial ☐ Monitor ☐ Test ☐ Farm ☐ Irrigation ☐ Heat Pump ☐ Municipal ☐ Other ☒ (Specify) <u>Transit</u>																																
(3) TYPE OF WORK Date drill rig left site: <u>10-27-12</u> New Well ☒ Deepen ☐ Rework ☐ Backfill And Abandon ☐		(11) PRIMARY CASING Diameter <u>4.5</u> Inches Top Set <u>24</u> Inches Above Ground From Land Surface to <u>380</u> Ft. below ground Type: Plastic ☐ Steel ☒ Galvanized ☐ Concrete ☐ Other ☐ None ☐ Wall Thickness <u>.237</u> or SDR # _____																																
(4) WELL COMPLETION DATA Date Completed <u>10/27/12</u> Static Level <u>97</u> Ft. Total Depth <u>437</u> Ft. Estimated Yield <u>650</u> GPM Depth to bedrock <u>5</u> Ft.		(12) WELL FINISH Open Hole ☐ Screen ☒ Slotted or Perf. Pipe ☐ From <u>380</u> Ft. To <u>400</u> Ft. If Screen, Plastic ☐ Metal ☐ Slot Size _____ In. Gravel Pack From <u>275</u> Ft. to <u>400</u> Ft.																																
(5) WATER-BEARING ZONES <table border="1"><thead><tr><th>DEPTH IN FT.</th><th>GPM</th><th>WATER QUALITY</th></tr></thead><tbody><tr><td><u>165</u></td><td><u>75</u></td><td><u>clear</u></td></tr><tr><td><u>245</u></td><td><u>75</u></td><td><u>clear</u></td></tr><tr><td><u>310</u></td><td><u>200</u></td><td><u>clear</u></td></tr><tr><td><u>400</u></td><td><u>300</u></td><td><u>clear</u></td></tr></tbody></table>		DEPTH IN FT.	GPM	WATER QUALITY	<u>165</u>	<u>75</u>	<u>clear</u>	<u>245</u>	<u>75</u>	<u>clear</u>	<u>310</u>	<u>200</u>	<u>clear</u>	<u>400</u>	<u>300</u>	<u>clear</u>	(13) BACK FILL MATERIAL Bentonite ☐ Cement ☐ From 3 Ft. to 10 Ft. <table border="1"><thead><tr><th>From</th><th>To</th><th>From</th><th>To</th></tr></thead><tbody><tr><td>Cuttings</td><td></td><td>Sand</td><td></td></tr><tr><td>Bentonite</td><td><u>surface</u></td><td>Cement</td><td><u>245</u> <u>275</u></td></tr><tr><td>Other (Specify)</td><td></td><td></td><td></td></tr></tbody></table>		From	To	From	To	Cuttings		Sand		Bentonite	<u>surface</u>	Cement	<u>245</u> <u>275</u>	Other (Specify)			
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(6) WELL TEST Tested By: Pumping ☐ Blowing ☒ Bailing ☐ Static Level _____ Ft. Pumping Level _____ Ft. After _____ Hr. Min. At _____ GPM Development Time Prior to Test _____ Hr. _____ Min.		(14) LINER CASING Yes ☐ No ☒ Type: Plastic ☐ Steel ☐ Diameter _____ In. From _____ Ft. to _____ Ft. Packers installed? Yes ☐ No ☐ Location: _____ Ft. and _____ Ft.																																
(7) FORMATION LOG <table border="1"><thead><tr><th>DEPTH IN FT.</th><th>DESCRIPTION (DENOTE ROCK COLOR&TYPES&CAVES)</th></tr></thead><tbody><tr><td>FROM TO</td><td></td></tr><tr><td><u>0</u> <u>5</u></td><td><u>Clay</u></td></tr><tr><td><u>5</u> <u>60</u></td><td><u>Sandstone</u></td></tr><tr><td><u>60</u> <u>437</u></td><td><u>Shale</u></td></tr><tr><td> </td><td> </td></tr><tr><td> </td><td> </td></tr><tr><td> </td><td> </td></tr><tr><td> </td><td> </td></tr><tr><td> </td><td> </td></tr></tbody></table>		DEPTH IN FT.	DESCRIPTION (DENOTE ROCK COLOR&TYPES&CAVES)	FROM TO		<u>0</u> <u>5</u>	<u>Clay</u>	<u>5</u> <u>60</u>	<u>Sandstone</u>	<u>60</u> <u>437</u>	<u>Shale</u>											(15) ANTICIPATED WATER QUALITY Clear ☒ Cloudy ☐ Dingy ☐ Muddy ☐ Good ☐ Fair ☐ Bad ☐ Iron ☐ Sulfur ☐ Gas ☐ Oil ☐ Salt ☐ Other ☐ (specify) _____												
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(16) GENERAL INFORMATION Well Disinfected: Yes ☒ No ☐																																		

(If additional space is needed, use back of form or use comments section)

Cable Mill Pump Test

11/5/2012 12:25 PM START

50% 17.5 GPM		100% 35GPM		150% 53 GPM		64 GPM	
Mininutes	Static 98.8	Mininutes	Static	Mininutes	Static	Mininutes	Static
1	100.0	1	102.3	1	110.3	1	111.9
2	100.1	2	102.4	2	108.4	2	112.0
3	100.1	3	102.6	3	108.4	3	112.1
4	100.1	4	102.8	4	108.4	4	112.1
5	100.1	5	102.8	5	108.4	5	112.1
6	100.1	6	103.1	6	108.4	6	112.1
7	100.2	7	103.5	7	108.5	7	112.1
8	100.2	8	103.5	8	108.5	8	112.1
9	100.2	9	103.5	9	108.5	9	112.1
10	100.2	10	103.5	10	108.5	10	112.2
12	100.2	12	103.6	12	108.6	12	112.2
14	100.3	14	103.6	14	108.7	14	112.2
16	100.3	16	103.6	16	108.7	16	112.2
18	100.3	18	103.7	18	108.7	18	112.2
20	100.3	20	103.7	20	108.7	20	112.2
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60 (1Hr)	100.5	60 (1Hr)	104.0	60 (1Hr)	109.0	60 (1Hr)	112.3
75	100.6	75	104.1	75	109.1	75	112.4
90	100.6	90	104.1	90	109.2	90	112.4
105	100.6	105	104.2	105	109.2	105	112.4
120 (2Hrs.)	100.7	120 (2Hrs.)	104.3	120 (2Hrs.)	109.3	120 (2Hrs.)	112.5
2.5Hrs	100.7	2.5Hrs	104.3	2.5Hrs	109.4	2.5Hrs	112.5
3 Hrs	100.8	3 Hrs	104.4	3 Hrs	109.5	3 Hrs	112.6
3.5 Hrs	100.8	3.5 Hrs	104.4	3.5 Hrs	109.5	3.5 Hrs	112.6
4 Hrs	100.8	4 Hrs	104.5	4 Hrs	109.6	4 Hrs	112.6
4.5 Hrs	100.9	4.5 Hrs	104.5	4.5 Hrs	109.6	4.5 Hrs	112.7
5 Hrs	100.9	5 Hrs	104.6	5 Hrs	109.6	5 Hrs	112.8
5.5 Hrs	100.9	5.5 Hrs	104.6	5.5 Hrs	109.7	5.5 Hrs	112.8
6 Hrs	101.1	6 Hrs	104.7	6 Hrs	109.7	6 Hrs	112.8

11/6/2012 12:25 PM STOP

Great Smoky Mountains, Cades Cove Well

November 5-6, 2012

