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September 30, 2014

Letter Report

To: Iron County Commissioner David Miller
From: Gary F. Player and Roice Nelson, Sr.
Subject: Proposed Water Well(s) on the Markagunt Plateau

INTRODUCTION

Much of this letter is condensed from the Final Report for completed work on Phase Two of the engineering services agreement between Cedar City Corporation and Gary F. Player for a geological and hydrological study of potential groundwater sources in bedrock aquifers near Cedar City. Field and laboratory studies reported in this document were completed during July and August of 2010.

Player completed reconnaissances of springs in Shurtz Canyon and flanking the Coal Creek-Crow Creek drainage system. Samples of bedrock formations were collected along Coal Creek and north of Crow Creek for description and determination of matrix porosity.

The best matrix porosity values (greater than 30 percent) were obtained from samples of Cretaceous sandstones that occur east of Right Hand Canyon along Highway 14. Rocks of the same age and physical properties are the sources of springs developed by the City in Shurtz and Right Hand Canyons.

Spring flow reported in Shurtz Canyon ranged from about 430 to 600 acre-feet from 1998 to 2001. Likely infiltration of precipitation each year in the same area ranges from about 900 to 1800 acre-feet. Therefore, at least 470 acre-feet, and as much as 1,200 acre-feet of high quality ground water remains to be produced each year from new wells drilled into Cretaceous rocks in Shurtz Canyon without depleting the aquifer system.

Similar rocks exposed along Coal Creek and Crow Creek also contain prolific aquifers that are now virtually untapped. The amount of water in those rocks available for development is much greater than the ground water water resources in Shurtz Canyon. Revised estimates of the water resource north of Cedar Canyon suggest that about 80,000 acre-feet of ground water are present within 1,000 feet of ground level within each 640 acre section. More than 10,000,000 acre-feet of ground water are

available for future development in the mountains north of Coal Creek and Crow Creek. Recharge into these rocks near Cedar Canyon may exceed 10,000 acre-feet each year.

Inflow to properly constructed wells in the Cretaceous aquifer adjacent to Cedar Canyon would be virtually unlimited by physical constraints. The amount of water available for development in wells will be limited only by water rights, access, and costs to drill wells into the relatively soft bedrock.

PROPOSED EXPLORATION WELL(S)

PROPOSED TEST WELL AT WOODS RANCH

The quickest and easiest place to drill east of Cedar City may be on lands owned by Iron County at the Woods Ranch recreation area. Water now utilized at the site comes from springs developed near the Kids' Pond reservoir. The County may welcome the opportunity to move their water rights into a prolific well.

A test well drilled at Woods Ranch should be placed to minimize obstruction to campers and sledders. One location I have chosen is near the western entrance, just across the entrance road to the east, and south of Highway 14. At that location, shallow, loose sand and gravel could be as thick as the 110 feet of unconsolidated materials present in the first Martin's Flat well. If present, those will be either flood plain or glacial outwash sediments deposited along Crow Creek that could contain high quality water in a shallow aquifer. Rocks below the loose sediments will be porous sandstones of the Cretaceous Lower Straight Cliffs and/or Dakota formations.

A Woods Ranch well could be drilled to a depth of 500 feet to 1,000 feet, depending on available funds. The well would penetrate Cretaceous rocks containing more than 250 feet of porous and permeable sandstones. The rocks may also be fractured by a fracture set that controls the orientation of the valley occupied by Kids' Pond, increasing the ability of the rocks to transmit large amounts of water into a well bore.

The following Table summarizes important information about the proposed well:

Test Well Name	Cadastral Survey	Latitude	Longitude	Elevation (feet)	Surface Ownership
Woods Ranch	SE ¼ sec. 18, T. 37 S., R, 9 W.	37° 35' 38.31" N	112° 55' 05.11" W	8172	Iron County

The specific Cadastral Survey location for well at Woods Ranch is approximately 1,400 feet E and 2,670 feet N from the SW corner of section 18, T. 36 S., R. 9 W.

PROPOSED TEST WELL AT MARTIN'S FLAT

Another quick and easy place to drill east of Cedar City would be on lands owned by Cedar City Corporation. The best ground water quality ever found in a City well occurs in Cretaceous sandstones penetrated in the Martin's Flat well drilled in 1951. A second well drilled there in 1966 only went to a total depth of 200 feet, and did not reach the prolific sandstones present below 195 feet in the 1951 well. I am now recommending a third well at Martin's Flat. The well should be drilled as close as possible to the hillside that flanks the flat to the west. At that location, shallow, loose sand and gravel will be much thinner than the 110 feet of unconsolidated materials present in the first well. Those were flood plain sediments (deposited by Coal Creek and Last Chance Canyon Creek) that can be avoided by drilling at the base of the hill. A well in that location could also encounter the fault and/or fractures that control the channel of Last Chance Canyon Creek.

This well could be drilled to a depth of 1,000 feet, if funds are available. The well would penetrate Cretaceous rocks containing up to 500 feet of porous and permeable sandstones similar to those encountered from 195 feet to 300 feet below ground level in the 1951 well. The rocks may also be heavily fractured, increasing their ability to transmit large amounts of water into a well bore. The first few feet of the well may penetrate loose sand and gravel, but fractured sedimentary rocks should be encountered less than 25 feet below ground level.

The following Table summarizes important information about proposed well Number Three:

Test Well Name	Cadastral Survey	Latitude	Longitude	Elevation (feet)	Surface Ownership
Martin's Flat	SW ¼ sec. 26, T. 36 S., R. 10 W.	37° 38' 29.78" N	112° 57' 15.21" W	6860	Cedar City Corporation

The specific Cadastral Survey location for a Martin's Flat well is approximately 1,525 feet E and 2,225 feet N from the SW corner of section 26, T. 36 S., R. 10 W.

PROPOSED TEST WELL AT DEER HAVEN CAMPGROUND

The proposed location of this well is on Forest Service lands northeast of Webster Flat Road, in Deer Haven Campground. The well would penetrate the youngest Cretaceous rocks on the Markagunt Plateau. These rocks, the Grand Castle-Wahweap Formation, have the thickest sandstones with the highest matrix porosity of any potential bedrock aquifer in Iron County.

A test well drilled on Forest Service lands should be placed to minimize environmental impacts to logging, recreation, and springs: an environmental review will be required before the Forest Service would allow a well to be drilled. Fortunately, road construction near the large group campground has already disturbed the pristine environment near Black Mountain. Water rights to two nearby small springs are now held by the Dixie National Forest, and are used to provide culinary water at the campground.

At Deer Haven, shallow, loose sand and gravel could be less than 50 feet thick, underlain by relatively soft Cretaceous sandstones and shales. A few tens of feet of hard, but permeable volcanic rocks like those that mantle the peak of nearby Black Mountain could also be present at shallow depths. Test Well Five should be drilled to a depth of 1,000 feet, depending on available funds. The well would penetrate uppermost Cretaceous rocks containing more than 500 feet of porous and permeable sandstones. The following Table summarizes important information about a proposed well:

Test Well Name	Cadastral Survey	Latitude	Longitude	Elevation (feet)	Surface Ownership
Deer Haven	SE ¼ sec. 19, T. 37 S., R. 9 W.	37° 34' 27" N	112° 54' 37.80" W	9140	USFS (Deer Haven)

The specific Cadastral Survey location for a Deer Haven well is approximately 1,000 feet E and 1,150 feet S from the NW corner of section 29, T. 37 S., R. 9 W.

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PROPOSED WELL CONSTRUCTION

The three wells discussed above should all be drilled as straight holes. Casing diameter should be on the order of 12" in the first five hundred feet in order to accept the installation of large capacity pumps. If one or more of the wells are continued to greater depths, the hole size can be reduced to allow the installation of slotted, 7" diameter steel casing (liners). Static water levels in each of the wells should

rise into the surface (12") casing from the lower intervals cased with 7" slotted liners. Final decisions on casing diameters and depths must be made by consultation with the selected drilling contractor.

The rocks to be encountered on the Markagunt Plateau can be penetrated by either rotary or cable tool drill rigs. Rotary rigs in some cases drill much faster. However, analysis of cuttings (rock fragments) and water levels is superior with cable tool rigs. For that reason, I recommend that the first well at either of the proposed locations be drilled with a cable tool rig.

TRANSPORT OF PRODUCED WATER

Water produced from high elevations can be pumped directly into Crow Creek for free transit to Coal Creek and Cedar City. However, water pumped into a pipeline can be used for generation of electricity with inline turbines. Selection of a method for water transport should be based on the economics of free creek transit, versus pipeline construction offset by electrical generation. That decision should be made by experienced engineers.

Roice Nelson has suggested that one or more wells drilled on the plateau above the Highway 14 landslide could be directionally oriented to emerge from the aquifer rocks near the channel of Coal Creek. In that case, water could be drained into the creek without any need for pumping. The possible advantages of such wells are: (1) water pressure against the cliffs above the highway would be reduced, thereby reducing the likely frequency of future rock slides; (2) pumping costs would be eliminated; and (3) electrical generating equipment (turbines) could be installed inside the well casing, allowing the well(s) to pay for themselves through the sale of electricity.

WATER STORED IN CEDAR MOUNTAIN, WEST OF CEDAR BREAKS, IRON COUNTY, UTAH

AREA	4	TOWNSHIPS	
AREA	144.00	SQ. MILES	
AREA	92,160.00	ACRES	
AREA	4,014,489,600.00	SQ. FEET	
GROSS THICK.	1,000.00	FEET	MINIMUM
GROSS THICK.	3,000.00	FEET	LIKELY
GROSS THICK.	5,000.00	FEET	MAXIMUM
SANDSTONE	0.40	VOL/VOL	MINIMUM
SANDSTONE	0.50	VOL/VOL	LIKELY
SANDSTONE	0.60	VOL/VOL	MAXIMUM
POROSITY	0.15	VOL/VOL	MINIMUM
POROSITY	0.20	VOL/VOL	LIKELY
POROSITY	0.25	VOL/VOL	MAXIMUM (INTERGRANULAR PLUS ALL FRACTURES)

VOLUME OF WATER = AREA * THICKNESS * SAND % * POROSITY

MINIMUM	5,529,600.00	ACRE-FEET
LIKELY	27,648,000.00	ACRE-FEET
MAXIMUM	69,120,000.00	ACRE-FEET

LIKELY VOLUME OF GROUND WATER IN PLACE UNDER 4 TOWNSHIPS:

27,648,000.00 ACRE-FEET

ANNUAL INFILTRATION

PRECIP.	15	INCHES PER YEAR	MINIMUM	1.25	FEET
PRECIP.	20	INCHES PER YEAR	LIKELY	1.67	FEET
PRECIP.	30	INCHES PER YEAR	MAXIMUM	2.50	FEET
AREA	4	TOWNSHIPS			
AREA	144.00	SQ. MILES			
AREA	92,160.00	ACRES			
AREA	4,014,489,600.00	SQ. FEET			
INFILTRATION	0.05	VOL/VOL	MINIMUM		
INFILTRATION	0.1	VOL/VOL	LIKELY		
INFILTRATION	0.15	VOL/VOL	MAXIMUM		

ANNUAL INFILTRATION = AREA * PRECIPITATION * INFILTRATION

MINIMUM	5,760.00	ACRE-FEET
LIKELY	15,360.00	ACRE-FEET
MAXIMUM	34,560.00	ACRE-FEET

LIKELY VOLUME OF INFILTRATION UNDER 4 TOWNSHIPS:

15,360.00 ACRE-FEET PER YEAR

THAT INFILTRATION AMOUNT WOULD PROVIDE THE "LIKELY" VOLUME OF GROUND WATER IN	1,800.00	YEARS

GARY F. PLAYER
03/24/08
rev. 07/03/14