Delineation of the Recharge Area for a Karst Spring Serving a Small Community on the Cumberland Plateau Escarpment

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Abstract

To meet Wellhead Protection requirements of the Safe Drinking Water Act of 1993, all public water systems must delineate a zone of protection around their ground water source. The purpose of delineating Wellhead Protection Areas is to define the geographic limits most critical to the protection of a well or spring. Use of water tracer techniques is costly and can present potential use problems to water customers in highly karst springs with relatively small contributing drainage areas. The incorporated Town of Orme, Tennessee, is supplied by Orme Spring. Orme Spring emerges from the north side of a karst window in the Monteagle Limestone. Orme Spring Wellhead Protection Area was delineated using surface reconnaissance, cave exploration as well as a cave map superimposed on the topography, and altimetry collected over different seasons of the year. With a good degree of confidence, a delineation of the area contributing recharge to Orme Spring was determined without the cost and possible water use disruption of a tracer study.

The Wellhead Protection Program for Public Water Systems in the USA was developed in response to the 1986 Amendments to the Federal Safe Drinking Water Act. The State of Tennessee adopted and began implementing this program in 1994. The purpose of the program is to define the recharge zones for all Public Water Supply ground water sources and protect these areas by a variety of means, including land use planning and community awareness.

This paper focuses on the water source for a small town in Marion County, Tennessee—the Town of Orme. Orme currently has a population of 93 people. It was originally developed as a coal mining industrial town located at the head of Doran Cove, a valley incised into the Cumberland Plateau of Alabama and Tennessee (see Figure 1). No coal has been deep mined from this area in more than 40 years. Today the town consists of a generally low- and moderate-income population, with a preponderance of senior citizens. The municipal water source is a spring (Orme Spring) discharging into a large sinkhole above the town and the entire water system is gravity fed. During normal flows, a small portion of the spring water is captured in a spring box and routed through sand filters to a holding/disinfection tank, which feeds the distribution system. During extended periods of very dry weather, the majority of the spring's output is captured for the water system. During periods following heavy rains, the turbidity of the spring water becomes high, necessitating the filtration system, which has been in existence for more than 25 years, having been constructed and maintained by various Federal aid programs to Appalachian communities. Figure 2 is a photograph looking up the valley toward the town and the escarpment where the spring is located.

The Tennessee Division of Water Supply undertook to aid the Town of Orme in delineating

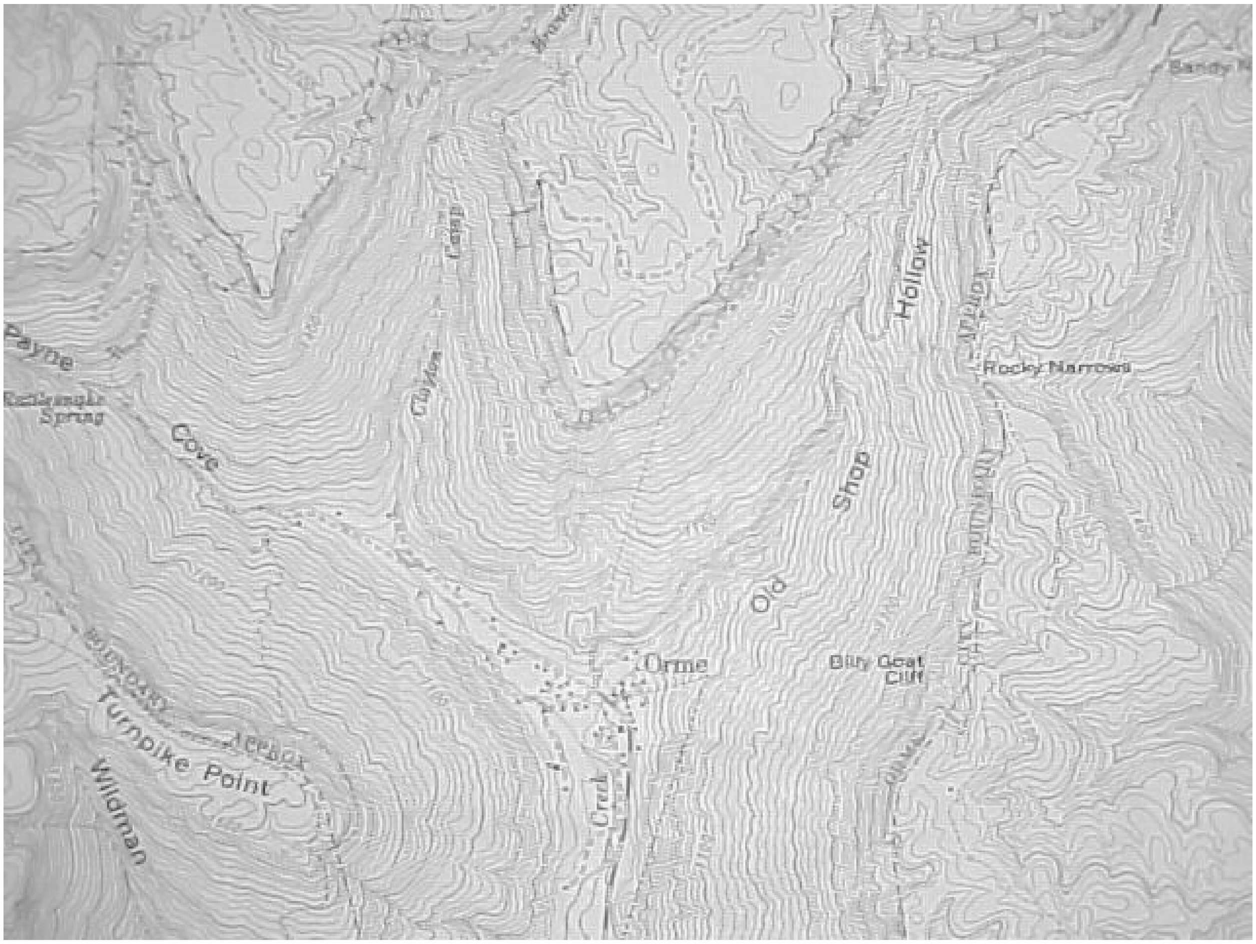

Figure 1: Topographic Map of the Orme, Tennessee, area.

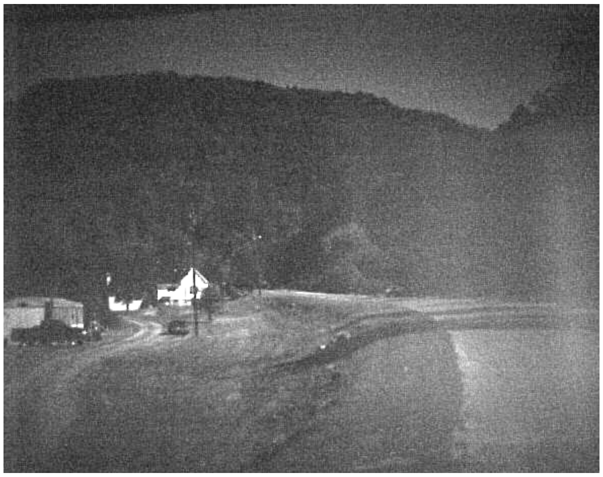

Figure 2: Doran Cove looking toward Orme and Orme Spring.

the recharge area for Orme Spring due to the financial circumstances of the municipality, even though the legal requirement for the determination is with the water supplier. Water tracer techniques using dyes or other materials were considered, but potential problems for the customers of the water system seemed probable from this because of the relatively small drainage area and the system's limited water storage capability. While not ruled out as a final resort, it was decided to develop the best picture possible of the flow patterns by surveying the locations and elevations of the various karst features.

The majority of the Town of Orme lies between 800 and 900 feet in elevation, while the Orme Spring issues at an elevation of 1,137 feet from the Monteagle Limestone and immediately plunges more than 50 feet into a sinkhole cave, also in the Monteagle (see Figure 3). Figure 4 is a diagram by Dr N.C. Crawford of the generalized geology and stream capture and resurgence patterns existing on the slope of the Cumberland Plateau. Figure 5 shows the karst and mining features identified up slope from Orme Spring in both the Clayton Camp Branch and Old Shop Hollow drainages, which flank Orme Spring on both the east and west, respectively.

Division of Water Supply personnel began the field investigation by walking the ridge of

Figure 3: Orme Spring, Showing Spring Box and Top of Waterfall.

the plateau above Orme Spring and the two drainage valleys noted above. Clayton Camp Branch did not have identifiable karst features of significant size and the stream did not appear to be losing any water. No obvious sinkholes were found on top of the plateau. In Old Shop Hollow, however, the stream was found to be sinking in at least two locations. A known and mapped stream cave, White Cricket Cave, also existed in this hollow, and a karst window was discovered near the valley floor below White Cricket Cave. White Cricket Cave is a significant stream cave formed at the contact between the Bangor Limestone and the Hartsell Shale. At the cave entrance, the stream falls over an impermeable layer in the Hartsell and flows underground a short distance to a karst window where it emerges and falls into the Monteagle Limestone. Approximately 160 vertical feet lower, the water emerges again and sinks in the karst window near the valley floor mentioned above. The elevation resolution of the topographic map was not sufficient to determine if the water from White Cricket Cave and the two karst windows might be above Orme Spring and, thus, a possible source to the spring.

Water quality and altimetry data were collected from the lower karst window and Orme Spring. No significant differences were found in the water quality data. However, the altimetry data showed an elevation of 1,107 feet for the insurgence point of the lower karst window, giving an elevation at least 30 feet below the elevation of the spring box at Orme Spring. Therefore, the water in the White Cricket Cave stream and the two karst windows does not contribute to Orme Spring. This discovery allowed a significant area on the east flank of Old Shop Hollow to be excluded from the Orme Spring Wellhead Protection Area. The splitting pattern for water in the upper reaches of Old Shop Hollow between Orme Spring and White Cricket Cave remained to be determined.

Seasonal observation of the discharge rates of Orme Spring, the White Cricket Cave stream, and the lower karst window, as well as both Clayton Camp Branch and Old Shop Hollow streams, added more information to determine the recharge area of Orme Spring. In the dry fall months Clayton Camp Branch had slightly less water than in the wet winter and spring months, while the uncaptured water at Orme Spring is just a trickle in the dry fall months but a raging waterfall in the wet season. This pattern supports the decision to exclude Clayton Camp Branch from the Wellhead Protection Area. During dry months White Cricket Cave and its two associated lower karst win-

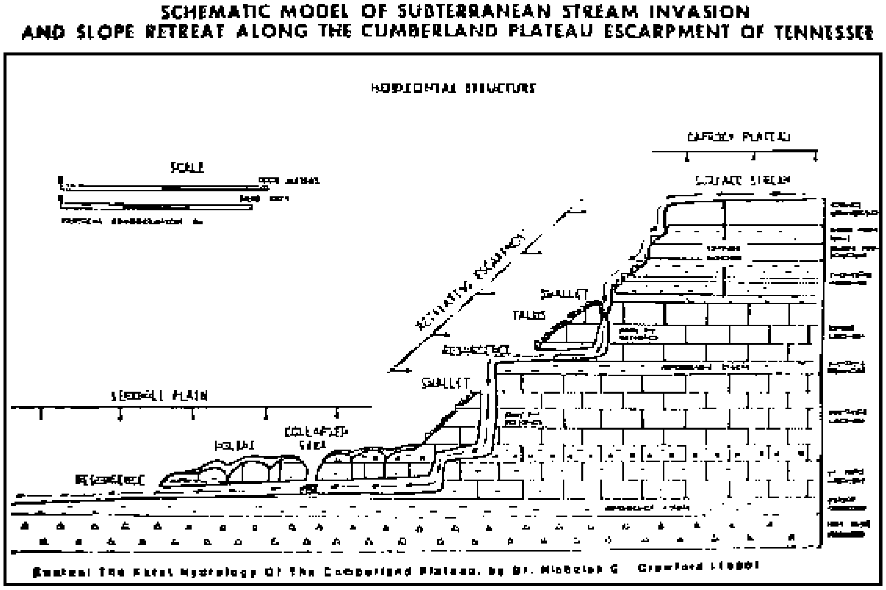

Figure 4: Schematic Model of Subterranean Stream Invasion and Slope Retreat along the Cumberland Plateau Escarpment of Tennessee. Source: The Karst Hydrology of the Cumberland Plateau, by Dr. Nicholas C. Crawford (1980)

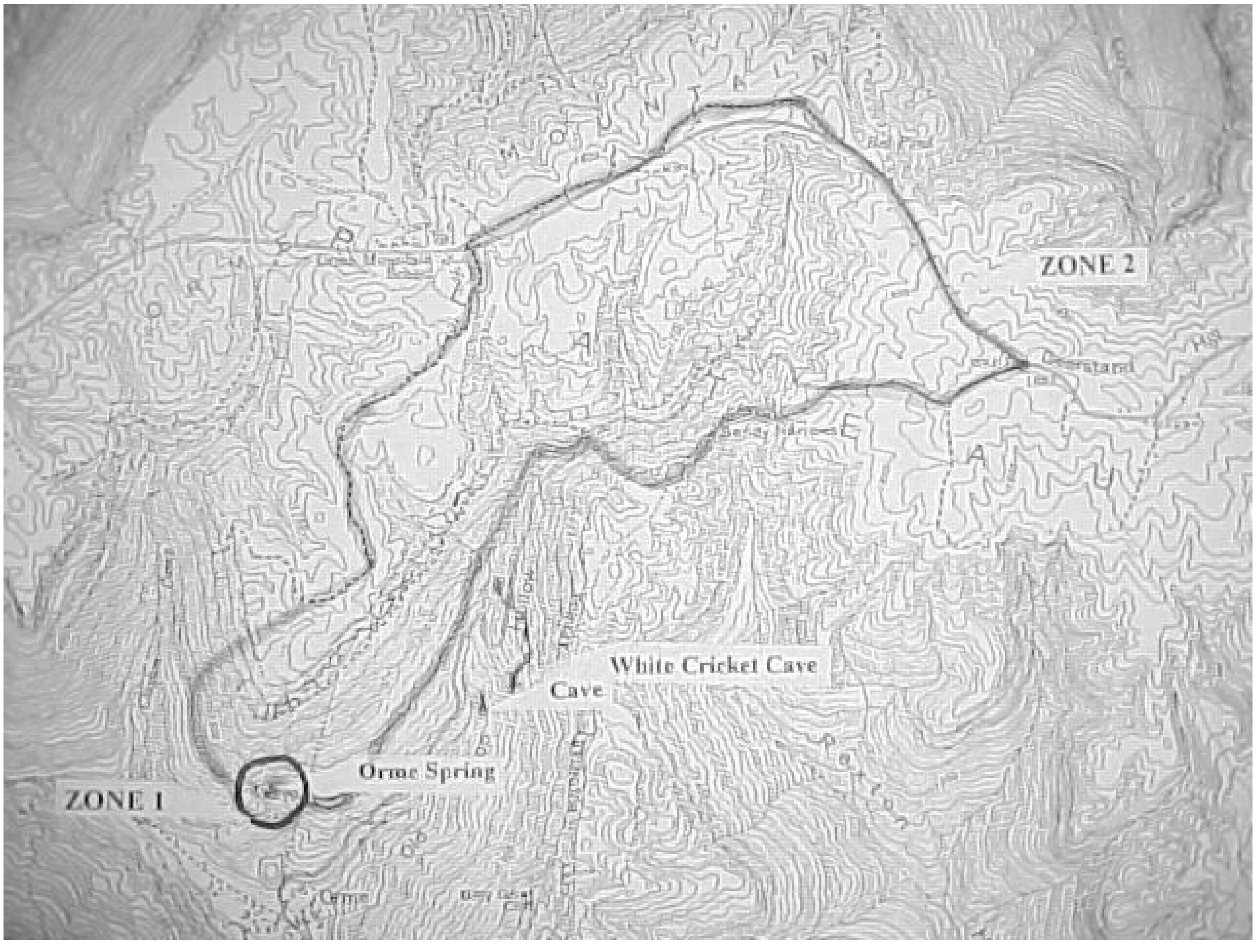

Figure 5: Wellhead Protection Area for Orme Spring, with Associated Karst Features.

dows have a much greater flow than Orme Spring, but in the wet months Orme Spring has a similar, or higher, discharge rate as the White Cricket Cave system. Because of this, the upper reaches of the Old Shop Hollow drainage must be feeding both the White Cricket and the Orme Spring karst systems, with White Cricket capturing most of the baseflow and the Orme Spring conduits taking progressively more of the flow as the upstream discharge increases. This mechanism explains the history of turbidity problems at Orme Spring following heavy rainfall events. All of the upper end of the Old Shop Hollow drainage was, therefore, included in the Orme Spring Wellhead Protection Area.

Figures 1 and 5 show a row of many deep mine portals above Orme Spring and Old Shop Hollow at the base of the plateau caprock. These are the openings to the extensive underground mining project of the Sewanee coal seam that once supported the economy of the Town of Orme. Now all are abandoned and several have discharges of mine water flowing down toward Old Shop Hollow and Orme Spring. Because of this, areas of the plateau in the vicinity of the mines were included in the recharge zone.

Figure 5 shows the final Wellhead Protection Zone as delineated by the above investigative process. This delineation was accomplished without the cost and possible water use disruptions of tracer studies and at no cost to the Town of Orme. The Division of Water Supply feels a good degree of confidence in the accuracy of this work and the delineated zone is now incorporated in the approved Wellhead Protection Plan for the Orme municipal water supply.

References

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Authors

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