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Karst Groundwater Issues Related to U.S. Forest Service Management Practices in the Daniel Boone National Forest, Kentucky, with Specific Focus on the Horse Lick Creek Ecosystem

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The U.S. Forest Service engages in numerous management practices on national forest lands. Some activities have only minor potential to degrade surface and groundwater while other activities have a high potential to impact these waters. Those activities associated with timber harvesting are considered to have a high potential to adversely affect water quality. The original and continuing mandate of the Service includes protection of the headwaters of streams. In karst terranes, surface and groundwater are conjunctive parts of a flow system; surface flow contributes to groundwater flow and groundwater flow to surface flow. It is therefore incumbent upon the agency to conduct management operations in such a manner as to minimize or eliminate degradation to any waters, surface or subsurface.

"Karst" is a term that refers to terranes often (but not always) characterized by surface landforms such as sinking streams, sinkholes, springs and caves, but more significantly refers to a particular type of subsurface hydrology in limestone strata where drainage is carried in conduits. This relatively rapid groundwater flow is usually facilitated by gradual dissolution of limestone along the horizontal and vertical fracture network of the bedrock. Most of this flow occurs at relatively shallow depths (less than

100 feet from surface), including a substantial portion in the epikarstic zone, that is, the weathered soil/bedrock interface zone.

Although in non-karst aquifers water flow is slow to very slow, measurable in terms of inches or feet per day, in karst landscapes subsurface water flow is typically very rapid and may travel thousands of feet per day through the conduit systems. As a consequence, pollutants may be transported long distances from point of origin to discharge in rivers, lakes, springs, or be intersected by wells, with little or no attenuation of the pollutants. In surface waters, many pollutants break down from exposure to sunlight and the actions of microorganisms. In the groundwater environment, by contrast, there is no photodecomposition of pollutants and conditions are encountered that greatly reduce microbial activity.

Although potential impacts are often immediate, the highly complex nature of many karst flow systems frequently creates a situation in which impacts can continue long after the initial spill or release. Within the caves and the far more numerous smaller conduits, pollutants are trapped in pools and pockets, on walls, ceilings and in sediments. The pollutants are then discharged in pulses following major precipitation events. In the epikarst zone, flood events can force pollutants into storage in overlying soils resulting in subsequent gradual release.

Detection and remediation of groundwater pollution under any sort of hydrogeologic setting is almost always a difficult, time-

consuming and expensive process. Monitoring wells, which are often used in non-karst regions to detect pollution, are much less effective in karst. As groundwater flow in karst regions is carried by conduits, wells must intersect a conduit in order to be effective. Drilling at random in an attempt to intersect conduits is not a feasible option. In karst regions it is far more effective to inventory and monitor local springs to detect pollution and ascertain its origin (if unknown).

In short, programs that are aimed at pollution prevention are more cost- and time-effective and more environmentally responsible than programs that take account only of cleanup or remediation. This is especially true for karst landscapes.

Forest Management Operations Having Greatest Potential Risk to Groundwater

There are several general areas of timber management operations where risk to groundwater can be identified. These include:

1. Pesticide/herbicide applications
   a. pre-harvest
   b. post-harvest
2. Siltation
3. Fuels and lubricants

Pesticides and herbicides are materials that by design are directly harmful to many forms of organic life (target species) and coincidentally may be toxic to a far greater range of non-target species. Environmental hazards involving pesticides occur during storage, handling, and applications. Improper storage and handling

may result in discharges of concentrates to groundwater. Applications, whether aerial or from the ground, give a wider distribution to less concentrated but still toxic materials. Applications may be made pre-harvest, for example in a program to control an infestation of gypsy moth, or post-harvest, as in control of undesirable vegetation following a cut.

Concerns regarding pesticides include but are not limited to off-site mobility, toxicity of decomposition by-products, and persistence in the environment. Pesticide use in timber management represents a very real threat to numerous life forms in the forest ecosystem, particularly when threatened or endangered species are involved. Many of the organisms that inhabit cave systems and subsurface waters are highly vulnerable to pesticides. Wide-scale use of chemicals should be carefully managed, particularly when a highly sensitive ecosystem is involved or when the area to be treated may drain to private or municipal water supplies.

Siltation and sedimentation occurs during harvest operations as a consequence of road building, creation of stream crossings, mechanical damage to land surface from equipment and cut timber, and reduced vegetative cover after a cut has been made. All of these practices disturb soils, increase erosion, and allow transport of sediments downstream. Heavy siltation can clog underground conduits and redirect drainage systems, and cause disruption of the ecosystem energy balance and loss of aquatic organisms. Excessive turbidity also reduces the quality of drinking water supplies derived from groundwater.

Fuels and lubricants are highly toxic to all forms of organic life. These materials can enter groundwater in a number of ways, ranging from leaking fuel storage tanks and machinery oil leaks to overfills and spills. Fuels, aided by rapid volatilization, will normally degrade quickly in open air. Once these materials enter subsurface systems the process of decomposition is greatly inhibited.

The key points to remember concerning groundwater in karst terranes are that:

(1) groundwater in conduit systems can travel very rapidly from point of infiltration to point of discharge

(2) pollutants can be carried relatively great distances

(3) pollutants may undergo very little attenuation or transformation while underground.

Implementation of best management practices (BMPs) can help to reduce or minimize risk to groundwater during timber management operations. Forest Service personnel involved in such operations or supervising harvest contracts conducted by others are the individuals with the greatest opportunity to identify practices that foster unacceptable risk to groundwater and to develop alternatives for implementation. Such individuals, however, must first be aware of the sensitivity of groundwater to contamination and the potential for widespread consequences.

Regulatory framework

Division of Water

The Kentucky Division of Water, through its several field offices across the state and the Water Quality Branch in Frankfort, regulates activities that impact surface waters, based upon existing surface water quality standards. At present, the USFS has entered into a Memorandum of Understanding with the Division of Water to voluntarily reduce sources of non-point pollution on national forest lands in Kentucky managed by the Service. BMP's are required by the Service in contracts with loggers, but implementation of these practices is variable and dependent upon effective monitoring by the Service.

Senate Bill 241

Kentucky's current proposed groundwater regulations, which focus on pollution prevention planning to be undertaken by industry, specifically exclude agriculture and forestry from this regulation. The potential impacts of agriculture and forestry practices on groundwater will be regulated under the provisions of Senate Bill 241. This bill has been passed by the state legislature and will go into effect in July 1994. The provisions of this bill will be implemented through creation of an agricultural water quality authority. Under the bill, silviculture is defined as an agricultural operation and falls within the purview of the authority's subcommittee on crops. The composition of the subcommittee will include a representative from the Kentucky Division of Forestry. Subcommittees will be formed to assist in

technical evaluations of practices to prevent water pollution.

The agricultural water quality authority is to develop, by July 1996, state-wide water quality plans to address concerns over pollution resulting from agricultural operations including forestry. Within five (5) years, persons engaged in such operations must implement the minimum requirements. These minimum requirements will address protection of surface water and groundwater.

The Horse Lick Drainage Basin and Ecosystem

Protection of groundwater from contamination can be said to derive from two major concerns, protecting the health of humans dependent upon groundwater consumption and also protecting the health of the ecosystem. While the human population is arguably part of the Horse Lick ecosystem, protection of human life and health must inarguably be a prime directive for any state or federal agency. The human population of the Horse Lick watershed is a small but significant number, of which 90 percent or more depend directly on self-supplied groundwater withdrawals for daily domestic use. The economy and infrastructure of the region does not at present nor in the near future allow the possibility that the more remote sections of the region will be served by a public water system.

The Horse Lick drainage also contains a number of threatened and endangered species, such as certain fresh-water mussels and several cave-dwelling organisms, that are relatively intolerant of

water quality degradation.

One of the primary points that must be understood about karst landscapes is that subsurface drainage does not necessarily coincide with the surface pattern of streams. Underground flow may originate far beyond the drainage divide of a particular stream, may cross beneath surface streams, and may discharge miles from the topographical divide. It is for these reasons that modern management practices at Mammoth Cave and Carlsbad national parks now include areas beyond the perimeter of the parks in environmental studies. However, for the Horse Lick conduit flow systems, the subsurface drainage pattern is somewhat more distinct and predictable, and more closely aligned with surface drainage patterns.

The geology of Horse Lick Creek, situated in western Jackson County, is characterized by having shaley limestone comprising the stream bed, with the accompanying ridges made up of 200-300 feet of limestone with sandstone caps. Extensive karst drainage networks have developed within these limestone units. There are numerous caves in the region and hundreds of springs that discharge into the stream, although many of the springs are visible only in wet weather. Based on research conducted by this writer in an adjoining stream basin, Crooked Creek, and research conducted by Sasowski (1992) on the Cumberland Plateau Escarpment in central Tennessee, karst drainage in the Horse Lick region appears to be strongly influenced by stress-relief fracturing. Briefly, this hypothesis indicates that, during valley development, flexing and

vertical fracturing of the bedrock peripheral to stream valleys occurs as the bedrock mass constituting the valley is removed through erosion. This creates preferential pathways for groundwater flow that are essentially parallel to surface valleys.

In form, these are conduits that are within the ridges, above the valleys, and parallel to surface drainage. The conduit drainage systems are fed by widespread infiltration, generally at the surface contact between the sandstone caprock and the underlying limestones. This is not universal, as this morphology is also strongly influenced by the regional dip of the bedrock and the amount of exposure of particular formations. Where the valley floor is comprised of limestones having a lower proportion of shales and other insolubles, cave systems develop under valleys rather than in ridges. This is most apparent in some tributary branches of local streams, whose development on relatively pure limestones is expressed through the presence of sinkholes and sinking streams -- so-called "dry valleys".

It is therefore apparent that management operations intended to minimize harmful impacts upon groundwater in karst systems must take into consideration very localized geologic and hydrologic characteristics. Where extensive strata of relatively pure limestones occur above valley floors, the sandstone/limestone contact will be one of the more sensitive locations for input of potential pollutants. This is particularly true for karst flow systems located along the Cumberland Escarpment in southern Kentucky, such as the region of Horse Lick Creek in Jackson

Counties. Where such limestones underlie valleys, then the entire valley must be considered as sensitive. When considering impacts upon karst terranes, management plans must take into account such differential aspects and not seek general solutions to be broadly applied.

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