MODEL ORDINANCE FOR DEVELOPMENT ON KARST IN KENTUCKY

Guidance for Construction on Karst Terrain and the Reduction of Property Damage
And Threat to Human Health Resulting from
Karst Geologic Hazards

For Consideration by Regional, County, and Municipal
Planning Authorities, Commissions, Boards, and Councils

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INTRODUCTION

I have dealt with hundreds of incidents of karst-related geohazards; some have caused major damage to buildings and infrastructure. Although cases are largely limited to the ground surface being made unusable, a significant number of structures are damaged by karst flooding or cover collapse each year, which is devastating to families who have lost their home. Most of these events should never have happened because the karst hazard could have been avoided by selecting a better building site or designing the building to withstand the damage from the hazard. Furthermore, most of the planning authorities I have had experience with seem mostly uninformed about the potential consequences of construction on these areas. They need more knowledge than simply the sense that something is wrong. They need to know what to do to avoid karst geohazards and mitigate damage. These experiences have motivated me to prepare this model ordinance for use by local government bodies to provide them with a template of how to minimize damage from karst geohazards.

The paradigm adopted for this document is to strive to work with nature. For example: retain runoff up-basin until the limited rate of flow into a swallow hole can carry the floodwater away, build houses above the spillover elevation of a karst valley, and filter out trash and sediment from a sinking stream. These techniques contrast with building ever-larger storm sewers that translate the excess runoff down the valley and cause other problems. Although both methods can be hydrologically effective, one is clearly more cost-effective. This document takes the work-with-nature approach, where it is an equal or better solution.

This model ordinance is intended as a source of text from which a Planning Authority may choose segments applicable to its experience, in its location, and the needs of its citizens. The model ordinance may be adopted in whole or in part. It can be modified, rewritten, or rearranged. Its provisions can be selected individually to supplement existing ordinances or the document as a whole can be used as a framework to develop an ordinance with predominantly new language, tailored to the local conditions and needs.

Text in *italics* is explanatory and may be deleted from the final document.

1.00: AUTHORITY

1.10. Statutory authorization: Through enactment of KRS 100, the Legislature of the Commonwealth of Kentucky has delegated the responsibility to local government units to adopt regulations designed to promote the public health, safety, and general welfare of its citizenry.

- 1.11. The provisions of this model ordinance are subject to existing statutes and regulations in effect at the State and local levels of government. In all cases where there is contradiction or redundancy, existing legislation takes precedent.
- 1.12. Immunity from liability: Use of this model ordinance in its entirety or any combination of chapters or paragraphs or any portion of text does not constitute a guarantee that property loss or bodily harm will not occur as a result of the geologic conditions addressed here. No warranty is made or implied of its provisions, of new construction built under any code based on these provisions, the level of compliance by the applicant, or enforcement by the Planning Authority.

1.20. Findings of fact:

- 1.21. The Kentucky Geological Survey estimates karst geohazards result in approximately $20 million dollars of economic loss to Kentucky per year.
- 1.22. Geologists have determined that much of the cost of damages resulting from karst can be avoided by carefully choosing building sites, building design, and site preparation.
- 1.23. Collapse or flooding caused by inadequate site preparation or inappropriate building design for structures located in or on sinkholes is a threat to persons residing or working in the structure and to the community as a whole in the form of damage to infrastructure.
- 1.24. Nearly all land parcels on karst terrains have buildable areas. By guiding construction away from vulnerable locations to locations more suited for building, significant costs to society from karst geohazards can be avoided.
- 1.25. Local government has a responsibility and right to protect tax-funded government infrastructure from damage by karst geologic hazards.
- 1.26. Government therefore has an interest in the proper siting and design of new structures and their accompanying infrastructure in karst areas (U.S. EPA, 2008).

1.30. Statement of purpose and intent:

- 1.31. The purpose of the model ordinance is to establish guidelines for review of development plans applicable to projects that encompass or affect karst.
- 1.32. The approach of this model ordinance is to proactively prevent damage by karst geohazards by avoiding construction in known geologically hazardous areas.
- 1.33. The ordinance does not include routine language describing positions within local government, the responsibilities of personnel in those positions, and technical details of design or required standards for infrastructure designed for mitigation of karst geohazards.

1.34. The model ordinance is not a mandated legislation or regulation on local governments, but rather a resource for the development of zoning and regulations by local government.

1.35. Unless expressly stated otherwise or contrary to context, the provisions of this chapter shall be interpreted and applied in accordance with the following guidelines.

(a) The effect of a project on stormwater management and groundwater quality must be identified and assessed. A mitigation plan presented in writing at the earliest stages of the development approval process (e.g., during the preliminary plat, development plan, or site plan approval stages) is highly desirable.

(b) The extent and sophistication of any required study should directly reflect the nature and complexity of the proposed development and of the development site. The more complex the karst features, the more extensive and sophisticated the study should be.

(c) The sections that follow establish generalized review procedures, limitations on use, design guidance, and performance standards applicable to site developments that encompass or affect sinkholes and other karst features.

1.40. Existing law:

1.41. Existing legislation and regulations passed at the State and local levels of government take precedence over this model ordinance in all cases where there is contradiction or redundancy.

1.42. It is recommended that the Planning Authority review current relevant Federal, State, and local statutes and regulations before adoption of any part of this ordinance.

1.43. All applicable Federal, State, and local permits shall be obtained prior to construction.

1.50. Organization of the model ordinance:

1.51. The ordinance is written in sections addressing the type of geologic hazard.

1.52. Each major component of the ordinance is given a whole number and the subsections are designated with decimals.

2.0: DEFINITIONS

The following section of definitions includes many karst-related technical terms, not all of which are used in the text of the ordinance. They are included as background information or in the event a Planning Authority develops a regulation in the future that uses the term. Therefore, all technical terms appearing in the adopted components of the model ordinance should be retained in the list of definitions adopted with the ordinance. Furthermore, it is recommended that the definition list be adopted intact. It will be necessary to supplement this glossary with definitions from existing building code, construction, and managed-growth plans relevant to development. Any definitions relevant to karst geology in existing ordinances should be replaced with these.

Base flow: Persistent rate of outflow of groundwater from a spring that is not influenced by rapid recharge from precipitation or snowmelt. Base flow is a steady or slowly decreasing discharge rate and has uniform physical water quality characteristics (for example, low turbidity). Summer base flow in Kentucky typically occurs from mid-June through mid-October, whereas winter base flow is slightly greater and persists between mid-December through mid-March.

Base level: Lowest level (elevation) in a study area of erosion by a stream or karst conduit. Mean sea level is normally the ultimate base level.

Bedding plane: A primary depositional lamination found in sedimentary rocks separating two strata of differing characteristics.

Bedrock aquifer: A rock formation, group of formations, or part of a formation that contains enough saturated, permeable material to yield significant quantities of water to wells and springs. Flow may be through pores, bedding planes, joints, fractures, or conduits.

Bedrock-collapse sinkhole: Formed by the collapse of a bedrock roof into an underlying cave. Bedrock collapse in karst is rare, but is the origin of some sinkholes, principally karst windows.

Bugs: Packets of material placed in springs to adsorb groundwater tracing dyes (see Passive tracer receptor).

Captured flow: See Pirated flow.

Cave: A natural opening created by dissolution or erosion of bedrock and large enough for an adult person to enter (Monroe, 1970). A diameter of 50 centimeters (20 inches) and a length (depth) of 2 meters (6.5 feet) are approximate minimum dimensions. Orientation of the dimensions of the opening relative to the bedrock outcrop is significant. An open-air vertical pit many feet deep and a few feet wide with minimal overhanging ledges is a cave, whereas an overhang in a cliff many feet wide and with a few feet of overhang is not a cave. In Kentucky, caves can exceed 30 meters (100 feet) in width and hundreds of miles in aggregated length. The flow of water in a cave may be perennial, seasonal, or high-flow (flood) only, or the cave may be permanently dry. An excavated underground mine or tunnel is not a cave.

Cave (location) radio: A paired radio transmitter and receiver that use very long wavelength, low-frequency radio signals to send a radio signal from a cave to the surface. The transmitted electromagnetic field is in the shape of a torus (donut shaped electromagnetic field) and can be detected at the surface through over 500 feet of rock. The point on the surface directly over the transmitter is found by locating the center of the torus shaped signal, which has a null signal or weak signal strength. Depth can also be calculated. Transmission depth is limited by the logistics of transporting batteries, delicate electronics, and a circular antenna that may be several feet in diameter through wet, low, or narrow and sinuous cave passages. Typically, cave radio is deployed at an important location (critical survey station in the cave, proposed excavated entrance, etc.) for which the precise location of the cave relative to the surface is required. Some designs include telegraph keys for underground-to-surface communication or are capable of surface-to-underground voice transmission.

Class V underground injection well (stormwater drainage wells): A disposal site in which surface-water runoff (rainwater or snowmelt) is diverted below the ground surface. They are typically shallow disposal systems designed to infiltrate stormwater runoff below the ground surface. Stormwater drainage wells may have a variety of designs and may be referred to by other names, including dry wells, bored wells, and infiltration galleries. The names may be misleading, so it is important to note that a Class V well by definition is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (with piping to enhance infiltration capabilities). For further details see www.epa.gov/safewater/uic/class5/types_stormwater.html

Conductance: See Specific electrical conductance

Conduit: A tubular opening created by dissolution of the bedrock, which carries, can carry, or has carried water. Conduits have a minimum diameter of 1 centimeter (1/2 inch) up to a maximum diameter of 50 centimeters (20 inches). Flow in a conduit may be year-round, seasonal, high-flow only, or the conduit may now be permanently dry. The minimum diameter is 1 centimeter, the approximate critical hydraulic diameter where water flow begins to transition to turbulent from smooth or laminar. Fundamental changes in the mechanisms of carbonate dissolution and groundwater flow occur as a result of a conduit reaching the 1 centimeter diameter.

Cover-collapse sinkhole: Formed by the collapse of the unconsolidated cover (soil, residuum, loess, or till) that formed the roof of a soil void or conduit at the soil-bedrock interface, or spanned a grike (cutter) or other karst void in the bedrock.

Developer (synonym: applicant, builder): Individual, limited liability corporation, for-profit corporation, nonprofit corporation, local or State government, public utility, or any other entity acting in cooperation to create residential, recreational, commercial, or industrial structures and other facilities.

Design storm: Total precipitation accumulating as a result of a storm of a predetermined duration and a specified probability of recurrence. The typical design storm used in Kentucky is of 100-year recurrence with 6-hour duration. Accumulation from such a storm ranges from 4 to 6.5 inches.

Distributary: Branching of a stream into multiple channels as flow approaches its local base level. Karst conduits frequently divide to discharge at multiple springs, at nearly the same elevation, located along the receiving stream.

Dissolution sinkhole (synonym: doline): Sinkhole resulting exclusively from gradual dissolution of the bedrock and removal of the dissolved rock and insoluble residuum via the sinkhole throat and karst aquifer conduits. Dissolution sinkholes may be totally buried and filled, or the bedrock may be totally exposed. Most dissolution sinkholes have the classic bowl-shaped contour, with a variable thickness of soil or other unconsolidated residuum covering the bedrock. (Also see Epikarst)

Dry well: (1) A well drilled into a karst sinkhole into which stormwater runoff is directed to minimize flooding of a sinkhole area. Such wells are conditionally included in the Class V injection well category by the U.S. Environmental Protection Agency. Also see Improved sinkhole. (2) A well, other than an improved sinkhole or subsurface fluid distribution system, completed above the water table so that its bottom and sides are typically dry except when receiving fluids. For further information see www.epa.gov/fedrgstr/EPA-WATER/1999/December/Day-07/w31048.htm

Epikarst (synonym: subcutaneous zone): The interval below the organic soil and above the mass of largely unweathered soluble bedrock, consisting of highly corroded bedrock, residuum, subsoil, loose rock in soil (float) and unconsolidated material of other origins. Thickness of the epikarst in Kentucky varies from absent to a reported 30 meters (100 feet). The epikarst is important for the storage and transport of soil water and groundwater in the karst system and is relevant to foundation stability.

Epikarstic dye introduction point: (1) A hole drilled through the soil and of very shallow depth into bedrock for the purpose of introducing groundwater tracers. A coarse gravel pack and casing are installed in the hole to direct inflow. The EDIP is tested for satisfactory inflow rate prior to introducing tracers. Tracer is commonly pre-mixed with water then pumped or poured into the hole. Additional water is added until the movement of the tracer into the epikarst is assured (George and others, 1999). (2) Trenches excavated to the top of bedrock and used to introduce tracers are not strictly EDIP's, but have a similar function.

Flood hazard/boundary map: The official map for the jurisdiction of the Planning Authority developed by the Federal Emergency Management Agency on which the boundaries of the flood hazard areas have been delineated.

Fluorescent Dye (synonym: tracer): One of several organic dyes that fluoresce under short wavelength light, particularly when dissolved in water or other solvent. Detection of the dye is confirmed by analysis of the mixture used to extract the dye from charcoal (elutant) or water samples with a fluorometer.

Geotechnics (geotechnical investigations): The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust to the solution of civil-engineering problems. It embraces the fields of soil mechanics and rock mechanics and other engineering aspects of geology, hydrology, and related sciences.

Graded filter: A method for filling sinkholes in which the sinkhole's throat in the bedrock is bridged with large pieces of stone. The layer of large stones is covered with a second layer of stones that are large enough to bridge the openings between the underlying stones. Layers of stone are laid down in courses until a final layer of fine gravel can be covered with soil and the surface can be graded.

Grike: A fissure in limestone bedrock developed by dissolution along a joint or other vertical or near-vertical fracture or uplifted bedding plane.

Groundwater basin: In a water-table aquifer, an area outlined on the surface through which groundwater flows toward a discharge zone or point. In karst, a groundwater basin can be larger than the associated surface-water drainage basin, if conduits extend outside of the topographical divide.

Gumdrop: Anchor fashioned from concrete and heavy-gauge wire that suspends a passive dye receptor above the bottom of a channel. A lanyard is tied from the gumdrop to a higher elevation to hold the anchor in place during high flow and so that the dye receptor can be retrieved easily.

Habitual trogloxenes: Animals that frequent the total-darkness areas of caves at certain times in their life cycle but live in other environments at other times and normally find their food above ground. The best known example is bats.

Hydric soils: A soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Hydric soils are one among several indicators used to characterize an area as a wetland.

Improved sinkhole: A naturally occurring karst depression or other natural crevice found in karst and volcanic terrain, among some other geologic settings, that have been modified by man for the purpose of directing and emplacing fluids into the subsurface. For further clarification see www.epa.gov/fedrgstr/EPA-WATER/1999/December/Day-07/w31048.htm.

Intermittent lake: A seasonal or ephemeral lake that inundates a broad karst depression or valley after major precipitation events. Intermittent lakes function hydrologically in a manner similar to a type of karst valley (poljes) that develop along faults, but intermittent lakes lack several diagnostic geologic characteristics of poljes. (Also see Sinkhole flooding)

Joint: A break in the continuity of the bedrock of geologic origin but without any visible movement parallel to the surface of the discontinuity.

Karst (synonym: Karst terrain, Karst terrane): A landscape generally underlain by limestone or dolomite, in which the topography is chiefly formed by dissolving the rock and that may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves (Monroe, 1970). The principal defining characteristic is the action of turbulent flow in conduits and caves, in the past or present. The term “terrain” implies that only the surface is considered, whereas “terrane” includes the subsurface (caves or aquifer) as a single system. Karst also forms on gypsum and salt bedrock, although not in Kentucky.

Karst aquifer: A body of soluble rock that conducts water principally via a connected network of tributary conduits, formed by the dissolution of the rock, which drain a groundwater basin and discharge to at least one perennial spring. The conduits may be partly or completely water-filled. The karst aquifer may also have primary (intergranular) and secondary porosity (fracture) that is saturated with water when below the water table.

Karst valley: A mid-size to valley-scale closed depression meeting the definition of a sinkhole but also enclosing and including more than one smaller sinkhole or a sinking stream.

Karst window: An unroofed section of a subterranean stream; a subterranean stream exposed to the surface within a sinkhole usually by collapse and dissolution and removal of a conduit’s roof.

Land tide (informal usage): Overland flow in a normally dry surface channel caused by the runoff rate from a storm exceeding the intake rate of swallow holes and/or the discharge carrying capacity of the underlying caves and conduits. The morphology of the surface channel may be a well-defined stream course or a disrupted channel that links spill points between sinkholes and ends at swallow holes.

Nonbuildable area (regulatory): Part(s) of the building site where construction is prohibited. The limits of the nonbuildable area are determined in the context of the type of construction and the type of hazard.

Passive tracer receptor (synonyms: bug, dye detector, dye receptor, passive charcoal detector): Consists of two general types. (1) The activated carbon receptor is constructed of a few grams of coconut-shell charcoal enclosed in a mesh bag typically made of nylon screen. (2) The cotton receptor is a section of untreated surgical cotton or bleached broadcloth. Tracer receptors are fastened to a gumdrop or field expedient anchor.

Pirated (basin, watershed) flow: The process by which one stream or cave enlarges its drainage basin area by expanding into a neighboring drainage basin and rerouting (capturing) that drainage to the enlarging basin.

Planning Authority (synonym: local government, Planning and Zoning): Any government body whose mandate is to promote the orderly growth and development of a community and that has legal authority to act on such petitions for development. Included in this definition are all staff, including the local government engineer and consultants working on behalf of the authority.

Ponor: See Sinkhole throat and Sinking stream.

Qualitative groundwater (dye) trace: Tracer experiment to establish the point-to-point connectivity, or flow vector, from the input point of the tracer to the resurgence. It only identifies the presence of tracer in the water (Worthington and Smart, 2003). The method of sampling is commonly by passive tracer receptors.

Recharge: The infiltration or direct inflow of precipitation, water from impoundments, and runoff as it leaves impervious surfaces into earth materials (soil, sand and gravel, fractured insoluble bedrock, or karstic bedrock) that results in the replenishment of groundwater.

Sinkhole: A closed depression in the land surface formed naturally by the erosion and transport of earth material from below the surface. A sinkhole is circumscribed by a closed topographic contour, internally drains to the subsurface, and is underlain by soluble bedrock. (Also see Cover-collapse sinkhole and Bedrock-collapse sinkhole)

Sinkhole cluster area: A group of two or more sinkholes clustered so that the average spacing among them is closer than the average among other sinkholes in the immediate area as a whole. A sinkhole cluster is likely to have a common groundwater basin.

Sinkhole flooding: Water temporarily ponded in a sinkhole resulting from precipitation or flow reversal in a conduit. The origin of the water is either runoff from the surface of the sinkhole watershed, which exceeds the intake capacity of the swallow hole, or reversal of the direction of groundwater flow, resulting in resurgent discharge from the throat of the sinkhole.

Sinkhole topographic plain: A planar surface on which most of the local relief is the result of sinkholes and nearly all drainage is underground.

Sinkhole rim: The projected line of approximately constant elevation circling the interior slope of a sinkhole and demarcating a change in slope from convex at the higher elevation to concave at the lower elevation. This term is difficult to define with clarity and should be used with discretion, if at all.

Sinkhole throat (informal usage): Outlet or outlets for a sinkhole allowing runoff from the sinkhole watershed to flow into the ground. Not all sinkhole throats exhibit a discernable opening or an opening large enough for a person to enter, but some have large dimensions and all are a sink point for an intermittent, seasonal, or perennial stream varying in flow rate from rivulet to rivers.

Sinkhole watershed: An area bounded by a projected line demarcating a change in slope from the center of the sinkhole to the outer boundaries of the sinkhole, which represents a local topographic drainage divide. Precipitation falling on the surface sloping toward the sinkhole is likely to run into the sinkhole throat, or infiltrate the soil and move through subsoil conduits to the throat.

Sinking stream: A surface-flowing stream that disappears underground.

Specific electrical conductance: The ability of a substance to conduct an electrical current. In hydrogeology, it is used as an indicator of the strength of dissolved minerals in water. It is measured in milliSiemens or microSiemens, the reciprocal of the resistance in ohms across a 1 centimeter cube of liquid water solution.

Spring: Any natural discharge of water from rock or soil onto the surface of the land or into a body of surface water.

Springshed: An area on the land surface bounded by a line projected vertically from the boundary between two karst groundwater basins. Precipitation falling inside of the springshed discharges at one spring, or an interconnected distributary of springs, at the local base level discharge zone. A springshed is analogous to a watershed but is frequently discordant with topography and can be dynamic in that the boundary can temporarily shift in response to unevenly distributed precipitation resulting in the activation of overflow routes, both overland and underground, into adjacent basins .

Swallet: Informal usage is generally synonymous with swallow hole. In formal use, a losing reach of alluvium-floored stream channel or other diffuse inflow of water into the underlying karstic bedrock.

Swallow hole: A place where water disappears underground into a hole in a stream bed or sinkhole.

Topography: The physical features of a landscape; hills, valleys, rivers, etc.

Topographic (watershed) divide: The boundary between two surface drainage systems, typically drawn along the crest of a hill. Water flows away from the divide.

Turbidity: A measure of sediment suspended in water by the scattering or adsorption of light.

Undeveloped land: Land not previously used for structures of any type. The following may be considered undeveloped land: areas that are largely forested, agricultural lands, lands with scattered single buildings such as farmsteads, a compact cluster of less than 12 buildings surrounded by open areas of fewer than 100 residents that are distinctly separate from larger communities, and other nonresidential uses.

Water table: The surface at the top of groundwater, below which water completely fills the pore spaces of the rock.

3.0: CRITERIA FOR IDENTIFYING SINKHOLES

3.10. A sinkhole described:

3.11. Description: A sinkhole is a closed depression in the land surface formed naturally by the erosion and transport of earth material from below the surface. A sinkhole is circumscribed by a closed topographic contour, internally drains to the subsurface, and is almost exclusively underlain by soluble bedrock. The dimensions of the depression and depth to bedrock have no bearing on the definition. The bedrock may be immediately subjacent to soil or separated from the surface by unconsolidated and consolidated cover many feet thick. The key criterion is that any precipitation falling within the interior of the sinkhole must drain out through the sides or bottom of the sinkhole, as opposed to draining overland, except when flooded.

3.12. Morphologies: Sinkholes formed in soluble rock include dissolution sinkholes (gently sloping depressions wider than they are deep), karst windows (sinkholes exposing underground streams), vertical shafts (depressions in bedrock much deeper than they are wide and roughly circular in plan view), grikes (depressions in soil and bedrock much deeper than they are wide and roughly lenticular or tapering in plan, and others. (Also see Sinkhole under definitions)

3.13. Closed topographic contour: An essential criterion for identifying a sinkhole. U.S. Geological Survey topographic maps identify and illustrate most of the larger depressions as closed contours with hachured marks on the interior side. Smaller sinkholes are commonly omitted on 1:24,000- and smaller-scale maps, but may be shown on larger-scale topographic maps with smaller contour intervals published by local government or similar maps by other public agencies or private companies. Many sinkholes are not represented on any existing topographic map. For all but the largest features, any given sinkhole might be shown on a large-scale map but not on a small-~scale map, it may not appear on an older map but is shown on a revision, or not shown on any available map but is observable in the field. The apparent size (plan view or vertical depth) of the closed depression is immaterial to the identification, but may be relevant to the selection or design of remediation or mitigation measures.

3.20. Criteria checklist for determining if a feature is a karst sinkhole.

(a) It must be a natural depression.
(b) The location must be underlain by soluble bedrock.
(c) The depression must be topographically closed.
(d) The depression must be internally drained.

The absence of sinkholes is not definitive evidence, however, of the absence of karst features at depth. Karst may underlie a site where there is no surface expression. Study of existing topographic maps, visual inspection in the field and aerial photography, possibly followed up with geophysical methods or drilling, are commonly necessary to determine the presence or absence of karst.

4.0: SIZE AND LOCATION OF SPRINGS AND SINKHOLES ON DEVELOPMENT PLANS

4.10. A site plan for the proposed development is required and the plan shall show all sinkholes and other karst features, as located and identified by a registered professional geologist or registered professional engineer in the Commonwealth of Kentucky.

4.11. All sinkholes to be shown on development plans: A sinkhole, a cluster of sinkholes, the immediate sinkhole drainage area, or sections of such areas as divided by property boundaries shall be shown on any preliminary development or subdivision plans.

4.12. Sinkholes found at the site but not illustrated on U.S. Geological Survey maps or local government maps shall also be shown. Large sinkholes or karst valleys with smaller interior sinkholes shall be mapped so that the smaller, interior sinkholes are also delineated. Sinkholes that have been filled in or buried shall be shown where there is any evidence of their location.

4.13. A new topographic survey may be required for tracts with closely spaced small sinkholes with a diameter of 3 feet or less. New topographic surveys shall use a contour interval (vertical separation) such that sinkholes of 1 ½ feet in depth are clearly shown. Sinkholes too small to contour shall be marked with a symbol that is explained in the map legend. The coordinates (latitude, longitude, and elevation) of the lowest point in the sinkhole shall be the reference point.

4.14. Karst springs shall be shown by the appropriate U.S. Geological Survey spring symbol, consisting of a circle with a tail in the direction of outflow, or, when the contours of the topographic map exhibit a deflection around the spring, by a symbol and the topographic contour.

4.15. All springs discharging water at any time shall be illustrated. Seasonal and perennial springs shall be differentiated by symbol. Perennial springs (flows all year) shall be shown as a filled-in circle and seasonal or intermittent springs shall be shown as an open circle. In the case that a spring distributary exists, the term “underflow spring” is applied to a spring that is at a minimal elevation among the distributary springs and flows perennially. The other springs are overflow springs at a marginally higher elevation and flow seasonally or intermittently.

4.20. Sinkholes: Avoidance and mitigation

4.21. Structures and infrastructure that should not be sited in sinkhole areas with a history of cover collapse or flooding are buildings with soil-bearing foundations, buildings that cover large areas (thousands of square feet) with impermeable surface, that use commercial scale onsite sewage disposal (septic tanks), and critical infrastructure nodes (transformer stations, natural gas booster stations, sewage pumping stations, telephone and cable distribution or switching stations, etc.) within the context of existing safety and zoning restrictions.

4.22. Newly formed or preexisting sinkholes that become active in a way that causes an immediate threat to nearby structures, roadways, persons, and/or property may be stabilized but must be filled by a method that meets accepted engineering standards. This subsection authorizes conditional, emergency action to remediate a hazardous situation. Any change in existing drainage patterns should be approved by the city engineer at the earliest possible time, and ideally before any mitigation is done.

4.30. Delineate areas underlain by cave passages.

4.31. Caves to be reported: All cave entrances on the project site shall be shown on the development plans. Caves discovered in the course of construction shall also be reported to the Planning Authority prior to any further construction. Any cave underlying a construction site discovered during construction shall be further explored by speleologists, geophysical techniques, or exploration drilling, and the findings submitted in writing to the Planning Authority.

4.32. Field verification of caves: Verification of the existence of a cave entrance(s) shall be made at the site by a registered professional geologist. The location of the entrance of any cave found shall be accurately plotted within a radius of 1 meter (3 feet) relative to the development plan map and shown on the development plan with a distinct symbol defined in the legend.

4.33. Historical documentation: Preexisting maps of caves and other evidence of caves within the development area may be recognized by the Planning Authority. Older maps must be accompanied by authenticating documentation (survey notes, photographs, etc.) that shows the map to be materially correct. Materially correct means the map documents the existence of the cave, its patterns and trends, its general depth below land surface, and is sufficiently accurate to indicate the area underlain by the cave at the scale of the building dimensions (tens of feet). The applicant may challenge the admission of such evidence within 30 days of its entry into the record or a maximum of 30 days prior to the next Planning Authority hearing on the development plan, whichever results in the earliest date.

4.34. If a map of the cave is available, the plan of the surveyed passages will be shown as a karst feature underlying the project area on the development plat. If the cave is known to extend under the development area but the entrance is off the plan area, the coordinates of the entrance shall be posted with an explanatory note. The developer should seek access to caves that are suspected of extending under the project area.

4.40. Contemporary cave surveys:

4.41. Maps of caves prepared from new surveys by third parties after the application for the development plan is submitted must include a statement on the map attesting to the accuracy of the map. The statement must be by the person(s) who drew the map of the cave and be notarized, or have the seal affixed of an engineer or surveyor registered in Kentucky.

4.42. Cave survey requirements: If it is probable a cave underlies a development area and an existing map cannot be found and the cave is accessible, a survey is required. The passage leading from the entrance to the area overlain by the construction and all passages underlying the development area that are accessible by commonly used speleological exploration techniques must be represented by a survey.

4.43. Investigation of inaccessible cave: If it is probable that a cave underlies a development area but it is inaccessible for surveying because (1) there is no known entrance, (2) the owner of the entrance will not give permission for access, (3) the passages are perennially flooded or otherwise blocked, (4) passages leading from the surface to the larger cave are unsafe because of pollution from any source (e.g., sewage, industrial wastes, or petroleum spills), then geophysical and geotechnical methods may be used to locate the cave. *If access to the entrance has been denied, the staff of the Planning Authority may negotiate with the entrance owner for access. Alternatively, another entrance may be excavated.*

4.44. Cave map accuracy: When put in effect by section 4.42, the new underground survey shall be made by a registered professional engineer or land surveyor or by an experienced cave surveyor under the oversight of a registered engineer or surveyor. When practical, equipment meeting accepted surveying practice shall be used. Where the underground conditions preclude the use of conventional surveying equipment, an accurate survey using smaller instruments (specifically, a high-quality compass) may be substituted. Use of a tripod is recommended, and use of handheld instruments is discouraged. If a compass is used, a minimum of two readings of the instruments must be made for each station-to-station traverse segment. All survey lines establishing a baseline for branching surveys shall be a closed circuit. Loop closure errors shall be within 0.5-percent of the loop length for magnetic surveys. Surveys made with a magnetic compass shall be adjusted for magnetic declination and meet or exceed BCRA Grade 6 (Dasher, 1994, p. 176). It is recommended that the accuracy of an existing map or new survey be further enhanced through the use of subsurface-to-surface cave radio.

4.50. General site requirements for foundations:

4.51. Thickness of cover: Depth between the ground surface and the cave roof shall be determined along the length of the cave for at least one of the following horizontal intervals: at every underground survey station or at every significant change in ceiling height of the cave. Where planned foundation excavations overlie the cave, and plans can be related to the cave passage, measurements of bedrock roof thickness are recommended at 3-foot intervals along the length of the passage for a total distance of twice the width of the passage, but in any case no less than three measurements must be made.

4.52. Soil-bearing foundation, minimum depth to cave passage: If development plans include placement of a structure with a soil-bearing foundation within the area determined by survey to be underlain by a cave, the minimum depth to the cave, as measured from the top of bedrock to the cave ceiling, shall be no less than twice the maximum width of the cave passage (Sowers, 1996), or as shown to be safe by a bearing-strength analysis conducted by a registered professional engineer with training and experience in rock mechanics.

4.53. Caisson and pin piling foundation, minimum depth to a cave: Load-bearing floors supported by caissons, pilings, or other foundation excavated to unweathered bedrock, and provided that the caissons are not underlain by deeper cave passages, shall be based on a bearing-strength analysis conducted by a registered professional engineer with training and experience in rock mechanics.

4.54. Alternative to minimum depth: If it is impossible to determine the depth to the cave ceiling, a nonbuildable zone shall be drawn around the plan of the cave so that no point of the foundation of the structures is less than 50 feet from the limits of the cave projected to the surface, but no closer than twice the maximum width of the cave passage, whichever is greater. The stability of the planned site for the foundation shall be demonstrated by geotechnical investigation.

4.55. Provision for variance: Variances from these provisions may be granted provided it can be shown that there will be no adverse effects to the karst aquifer, the stability of the foundation of the structures and associated infrastructure can be warranted for the foreseeable future, and it can be demonstrated there will be no negative impact on existing structures and infrastructure.

4.60. Karst-related nonbuildable areas:

4.61. The Planning Authority shall determine or delegate to staff to recommend a determination of nonbuildable areas resulting from the presence of geologic hazards associated with karst. Areas so designated must be clearly a hazard and the designation shall be applied to the minimum area possible.

4.62. Nonbuildable and restricted fill areas determined from sinkhole locations shall be shown on final subdivision or other development plans.

4.63. A nonbuildable area delineation is based upon the topography, geology, soils, history of the sinkhole (such as past filling), and the applicant's engineer's stormwater analysis and geotechnical investigations or determined from the historical record of previous flooding and collapse. Other karst features in the plan area, such as springs and caves, may also be a justification for delineating a nonbuildable area.

4.64. The boundary of the nonbuildable area for a single sinkhole or cluster of sinkholes shall be the sinkhole spillover elevation.

4.65. No buildings, parking areas, grading, or other structures shall be permitted within the sinkhole-related nonbuildable area unless a variance has been authorized by the Planning Authority.

4.66.. No private drives, streets, and highways shall be permitted within the sinkhole-related nonbuildable area unless the Regional Highway Engineer and the Planning Authority conclude that traffic safety considerations are imperative and significantly outweigh avoidance of potential collapse and stormwater water-quality considerations.

4.67. Cave entrances to be preserved: The cave entrance shall be preserved in a secure, safe, and controlled accessibility condition for continuing examination of ceiling stability, survey of additional passages, or other scientific and geotechnical investigations. A substantial and lockable cave gate may be required. The cave entrance shall have a buffer zone established that is adequate to exclude the entrance from view from homes in the development and provide for sheltering of cave wildlife classified as habitual trogloxenes from routine human activity.

4.68. Nonbuildable areas may be used to meet other planning provisions such as green space, recreational areas, or noise buffer requirements, provided all other relevant planning provisions are met.

5.0: DETERMINATION OF RISK OF FLOODING

Note: This section of the model ordinance does not address surface (above-ground) flow from springs that discharge immediately to streams outside of karst areas, fluvial or riverine flooding, storm surge, or tidal flooding.

5.01. The intent of this section is to require all development plans to ensure that the rate and volume of runoff after development is not significantly different than if the site were undeveloped karst.

5.02. Construction within 300 feet of a sinkhole throat or the swallow hole of a sinking stream shall use the best available management practices, which must prevent sediment being deposited in the sinkhole outlet.

5.03. Filling of a sinkhole: Burial, leveling, or disposal of clay, topsoil, or debris from blasting of bedrock debris in a sinkhole or sinking stream without providing for maintaining the inflow rate is prohibited. Regrading near or in the sinkhole throat in a haphazard, unstructured manner of earth materials that are likely to become compacted and minimally permeable during grading or over time is prohibited as infill.

5.04. Construction planned inside any depression qualifying as a sinkhole (see definitions) or within the watershed area of a sinkhole that has been filled in, in whole or in part, shall comply with the requirements for prevention of flood damage.

5.05. It is necessary to take into account the hydrology of the entire area of a springshed (watershed) when establishing flood hazard boundaries and stormwater management structures, Planning Authority boundaries that cross springsheds (watersheds) should be administratively eliminated through cooperative, joint Planning Authorities (at least for consideration of any development that includes both administrative and watershed boundaries).

5.06. The applicant shall determine if a Federal Emergency Management Agency (FEMA) Flood Hazard Boundary Map exists on which any areas covered by the Flood Insurance Program that are relevant to the development project are delineated. The applicant shall obtain copies of flood hazard maps that include all of the development project area but particularly the areas where a flood hazard is indicated. Irrespective that the availability of flood insurance is based on the FEMA boundary, the applicant must also prepare a site-specific karst flood hazard map.

5.10. Applicant is required to determine maximum possible flood elevation.

5.11. If a Federal Emergency Management Agency Flood hazard boundary has been drawn for any sinkhole in the development project area, that flood boundary shall be compared to the flood boundary drawn by the applicant. Both boundaries shall be illustrated on the development plans. The boundary with the highest flood elevation shall determine the buildable and nonbuildable areas (Matheney, 1984).

5.12. Storm design: It is recommended but not required that the applicant use the local record precipitation when planning construction. The record precipitation event for Kentucky is the storm of June 28, 1960, when the 24-hour accumulation at Dunmor was 10.40 inches (Conner, 2008). (The record daily precipitation for most communities is available from the Kentucky Climate Center and the University of Kentucky Agricultural Weather Center, as well as other State and Federal agencies.)

5.13. For the purposes of this ordinance, two standard storm events shall be used if the record storm is not used: 6-hour and 24-hour accumulation, both for 100-year return frequency storms. The 6-hour event is the standard for most existing planning ordinances and is cited in this ordinance. The 24-hour event, however, is strongly recommended (Smith and Vance, 1997). *In reality the pore space from the ground surface down through the epikarst becomes saturated during any lasting storm event. The 24-hour model, by simulating saturation, will reveal problems that the shorter-duration model does not.)*

5.14. Applicant is required to show sinkholes that flood on the development plan; all sinkholes within the development area shall be evaluated for flooding potential. Those that have a history of flooding are to be indicated by a flood elevation contour, as defined in the legend; the meaning of the symbol must be explained in a note to be attached to the development plan.

5.15. Criteria to be used to determine if a sinkhole floods: If any of the following criteria are met, the sinkhole is assumed to flood, until further study proves that it does not flood. The absence of these criteria does not exclude all risk of flooding.

(a) Report by a credible local resident who had the capacity to observe and make a contemporaneous, dated written or photographic record of the extent of the flooding.
(b) Formal photographic evidence (aerial or ground-level) with an accurate record of date of the flooding.
(c) Hydrograph stage records that show flooding from any storm.
(d) Hydrologic modeling that predicts flooding from a 100-year, 6-hour storm.
(e) Extensive presence of hydric soils.

5.20. Applicant must maintain existing rate of runoff or reduce runoff: The rate of stormwater flow into a sinkhole shall be maintained at the predevelopment rate (determined by hydrograph response), or the runoff rate may be reduced. Any increases in total runoff, shortening of the time of concentration for the watershed, or routing of drainage from an adjacent watershed are prohibited unless mitigation measures can be demonstrated to be effective and specifications for their design and construction are attached as a note to the development plan. Detention basins, retention basins, and other hydrologic structures are required if an increase in runoff or a shortening of the time of concentrations are indicated.

5.30. Applicant may present arguments to demonstrate no risk of flooding for a sinkhole or a construction site within the development area. “Construction site” means the footprint of any structure or infrastructure that could be damaged by floodwater. Areas within the development property that are otherwise designated as nonbuildable or as green space are excluded from this provision for variance.

5.31. Assurance that a specific sinkhole does not flood: A digital hydrologic model is an acceptable method to demonstrate that an entire sinkhole or karst valley does not flood (Mills and others, 1991). The digital model may be run for the local 6-hour, 100-year design storm *(approximately 4.7 inches accumulation in Kentucky)*, but a 24-hour duration is recommended. The hydrologic conditions set shall assume no outflow from the sinkhole. All man-made surfaces are modeled as impervious, soils are modeled as saturated, and evaporation and plant transpiration are absent. The results of such a model shall not negate physical evidence to the contrary, however (section 5.10). If the sinkhole outflow has been determined, a documented, demonstrable maximum rate of outflow into the sinkhole throat (or an existing dry well) may be used, although the availability of such data implies some flooding occurs. A reliable observation or historical record of the absence of flooding during a 100-year return frequency, 24-hour storm on saturated soil may be taken into consideration by the Planning Authority.

5.32. Construction site in sinkhole but not in flood zone: The applicant may demonstrate that the proposed construction site is above the maximum possible flood elevation. The applicant will use a digital hydrologic model, and the model shall be run per the specifications in 5.31. The hydrologic conditions used in the model shall assume no outflow or, if rate of outflow has been determined, a documented, demonstrable maximum rate of outflow from the sinkhole may be used. The results of such a model shall not negate physical evidence to the contrary, however (section 5.15). A reliable observation or historical record of the absence of flooding during a 100-year return frequency, 24-hour storm on saturated soil may be taken into consideration by the Planning Authority. If the report is found to be credible by the Planning Authority, construction may be permissible in regard to flooding.

5.33. Construction site stated to be above the sinkhole spillover elevation:

(a) The lowest elevation point on the sinkhole watershed boundary is the hypothetical spillover elevation when the sinkhole is filled.

(b) The applicant shall determine if a sinkhole is interior to a larger compound sinkhole or karst valley. This may be accomplished simply by inspection of a topographic map. If the sinkhole is part of a karst valley, the higher spillover elevation of the enclosing watershed must be presumed to be the maximum flood elevation until the potential for flooding is assessed.

(c) Runoff from the development property must be maintained or reduced below predevelopment rates, per section 5.2.

(d) Provided that section 5.33(b) is satisfied, if the lowest elevation of the construction site is above the spillover elevation, and other evidence for flooding has not been demonstrated or presented to the Planning Authority, the construction is permissible in regard to flooding.

5.40. Storage of excess runoff within the sinkhole watershed.

5.41. Stormwater detention facilities may be constructed within the sinkhole watershed or the area of the sinkhole outside of the sinkhole flooding area, as determined for post-development conditions.

5.42. Sinkhole as detention basin: The Planning Authority staff may recommend waiver of up-gradient detention requirements to allow increased runoff into sinkholes and may authorize construction within a sinkhole flooding area to provide additional water detention, upon finding that all of the following apply:

(a) Flooding will not be worsened down-gradient of the sinkhole.

(b) The use of the sinkhole for detention will not cause a cover collapse.

(c) There are no other areas on the site suitable for runoff detention.

(d) There will be no significant impact on the karst aquifer or the quality of the water.

5.43. Designs for runoff-control structures that maintain runoff inflow to sinkholes at the natural (predevelopment) rate shall be prepared by a civil engineer and approved by the Planning Authority. The detention basin volume shall be determined with data from a runoff digital model using the same type of input described in section 5.31.The specifications for construction of the dam and other control structures shall be designed based on the same runoff model and the specifications posted on the final development plan.

5.44. A drainage easement covering the post-development flooding area shall be provided for any off-site sinkhole or part of a sinkhole that receives increased peak rates of runoff from the site. If the receiving sinkhole is not contiguous to the site, an easement must also be provided for any overland waterway that connects the site to the sinkhole (Dinger and Rebmann, 1986).

5.50. Modification of sinkholes to change outflow rates.

5.51. Increasing recharge rates of sinkholes by excavating the sinkhole throat or installing dry wells for diverting surface runoff to the groundwater system is defined as improving a sinkhole, and the sinkhole is classified as a Class V injection well by the U.S. Environmental Protection Agency (October 2008). Because the EPA has administrative control in Kentucky, the inventory information and any applicable permits must be submitted to the EPA.

Also see the Stormwater Drainage Wells Web site at www.epa.gov/safewater/uic/class5/types_stormwater.html. Provide basic `inventory information' to the Underground Injection Control (UIC) Director for your area before you begin construction. Enter the information on the form "Inventory of Injection Wells,"' OMB No. 2040-0042. A link to a PDF version of this form and to a summary of BMP's for injected stormwater may be found on the EPA Web site at www.epa.gov/safewater/uic/class5/5ypes_stormwater.htlml. You will also need to provide any additional information that your UIC Program Director requests in accordance with the provisions of the UIC regulations.

5.52. Dry wells (Class V injection wells) are strongly discouraged and the Planning Authority shall enforce all of the provisions in the ordinance for preventing flooding, both at the well and in lower-elevation sinkholes down-gradient. Treatment of runoff for water quality improvement prior to injection is required.

5.53. New dry wells may be approved only by variance directly by the Planning Authority and only if conditions (a) or (b) below are met and also condition (c) (City of Hopkinsville, 2002):

(a) It is demonstrated to the satisfaction of the Planning Authority that such an action is necessary to safeguard persons or property from a clear and imminent danger, or

(b) Such an action is required to implement the drainage and/or erosion-control plan that was approved by the Planning Authority after evidence of the necessity of the injection well is demonstrated with good and sufficient cause.

(c) The appropriate inventory form has been submitted to the correct EPA address on a timely basis sufficient for reply (90 days prior to construction).

5.54. In cases where there is potential for runoff carrying a concentrated sediment load directed to sinkholes to occur during construction, temporary (or permanent) erosion-control measures, as detailed in a plan preapproved by the Authority, shall be implemented. See section 6.0 for additional guidance.

6.0: MEASURES TO PROTECT GROUNDWATER FROM PHYSICAL, BIOLOGICAL, OR CHEMICAL POLLUTION

6.10. Existing legislation and regulations:

6.11. The provisions of this model ordinance are subordinate to existing legislation or regulation. Further guidance for both the Planning Authority and the applicant can be found in the draft document "Kentucky Best Management Practices (BMP's) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites: Planning and Technical Specifications Manual" (Tetra Tech, 2006, available at www.water.ky.gov/sw/nps/Publications.htm.

6.12. Dumping waste or infilling of sinkholes regulated: The disposal of any debris, trash, construction debris, garbage, junk, lawn waste, or other waste of any type in a sinkhole or sinking stream is prohibited.

6.20. Groundwater Risk and Vulnerability:

6.21. Groundwater contamination risk: All karst aquifers are sensitive to groundwater contamination. The proximity of a sinkhole with open throats or a sinking stream to a source of pollution makes the aquifer much more vulnerable (Smith and Vance, 1997).

6.22. The relative risk for groundwater contamination in karst areas shall be defined and classified as low, moderate, or high, depending upon the type of proposed land use, development density, and area of impervious area directly draining to and connected with a dry well or sinkhole (Monroe County, Ind., undated).

6.23. Low risk: The following land uses are classified as posing a relatively low contamination risk to groundwater:
(a) Residential developments on sewer and with contiguous impervious areas of less than 1 acre that discharge directly to a sinkhole.
(b) Parks and other recreation areas.
(c) Commercial and office developments with contiguous impervious areas of less than 1 acre that discharge to the sinkhole.

6.24. Intermediate risk: The following land uses are classified as posing a relatively moderate contamination hazard to groundwater:
(a) Areas with significant quantities of runoff from streets, parking lots, and roofs with contiguous impervious areas of more than 1 acre and less than or equal to 5 acres discharging directly to a sinkhole.
(b) Multifamily residential developments and higher-density office developments, provided the directly connected impervious areas discharging to the sinkhole are less than or equal to 5 acres.

6.25. High risk: The following land uses are classified as posing a high contamination hazard to groundwater:
(a) High-traffic arterial streets and highways.
(b) Railroads.
(c) Concentrated and large quantities of runoff from streets, parking lots, roofs with contiguous impervious areas of greater than 5 acres discharging directly to a sinkhole.
(d) Industrial and manufacturing and high-traffic commercial areas.
(e) Onsite wastewater disposal systems.
(f) Concentrated livestock holding or feeding areas.

6.30. Sediment erosion- and pollution-control measures for groundwater in karst:

Developments with high-risk land use will utilize as many of the following practices as possible, depending on site conditions and the judgment of staff with the approval of the Planning Authority. (*The Planning Authority may promulgate regulations that provide that if the area is low risk, developments must use sections 6.31, 6.32, and 6.34 as a minimum standard. If the risk is moderate, all of the provisions should be enacted, except either section 6.33 or 6.39 may be eliminated, but not both. At their option, applicants for moderate- and low-risk developments may use all or any combination of methods that include the minimum set out above.*)

6.31. Additional BMP's for the construction and management of dry wells and improved sinkholes may be found at www.epa.gov/safewater/uic/class5/pdf/page_uic-class5_storm_water_bmps.pdf.

6.32. Sediment and erosion control: Existing ground cover shall not be removed within 25 feet of the sinkhole flooding area, and a temporary silt barrier shall be erected and maintained around the outer perimeter of the buffer area during the construction period (Tetra Tech, 2006).

6.33. Vegetative cover must be of sufficient quality and density to provide substantive and effective filtration. If existing vegetative cover is sparse, it must be improved to sufficient quality and density to provide the desired filtration.

6.34. A sediment basin is required at each point where collected runoff is discharged into the sinkhole as a stream. Sediment basins shall be designed according to criteria set forth in the Kentucky Erosion Prevention and Sediment Control Field Guide (Tetra Tech, 2006). A permanent sediment basin may be required in some cases. The indication that a permanent sediment basin is needed shall be based on the watershed area, the disturbance that the proposed project will create, the land use when the project is finished, and the availability of suitable sites for a sediment basin.

6.40. Minimizing the area of contiguous impervious surface: Impervious areas can be subdivided by providing grass swales, sized according to the area producing runoff, and vegetative filter strips.

6.41. Diversion of runoff: Concentrated discharges to sinkholes can be reduced to manageable levels or avoided by diverting runoff from impervious areas away from sinkholes where possible. Diversions shall be done in a manner that does not increase flooding hazards on downstream properties and, where possible, shall be directed out of the surface watershed in which the sinkhole is located (Dinger and Rebmann, 1986).

6.42. Filtration areas: For areas having a low groundwater contamination sensitivity and where flow into the sinkhole occurs predominantly as sheet flow, water quality can be satisfactorily protected by a permanent vegetative buffer area with a minimum width of 25 feet around the sinkhole flooding area.

6.43. Grassed swales and channels: For areas having a low groundwater contamination hazard, concentrated flows from contiguous impervious areas of less than 1 acre may be discharged into a sinkhole through grassed swales and channels.

6.44. Swales and channels shall be designed for nonerosive velocities and appropriate temporary erosion-control measures such as sodding or erosion-control blankets shall be provided.

6.45. Storage and infiltration: Storage and infiltration basins shall be designed to capture and hold the first 0.5 inch of excess runoff from the tributary drainage area. Additional excess runoff shall be detained and released over a minimum period of 24 hours.

6.50. Proposed facilities to manufacture, transport, utilize, repackage, or otherwise handle hazardous or other dangerous materials, which have the potential to enter the groundwater, shall also comply with the regulations of the Kentucky Department for Environmental Protection.

7.0: PREVENTION OF HAZARDOUS ACCUMULATIONS OF RADON IN NEW CONSTRUCTION

Note: This ordinance does not mandate retrofitting of preexisting structures.

7.10. Building permits shall not be issued for buildings that are occupied more than 6 hours per day and 30 hours per week without an estimate of radon radiation in a standard-design (no radon mitigation) area of the structure.

7.11. Standards for new construction can also be found at www.wbdg.org/ccb/DOD/UFC/ufc_3_490_04a.pdf.

7.12. Citizens are encouraged to have their home tested for radon (U.S. Department of Health and Human Services, 2005). More information can be found at the Cabinet for Health and Family Services Web site at chfs.ky.gov/dph/info/phps/radongas/.

7.13. Scientists' understanding of how radon enters a building, and testing and mitigation procedures for radon, are constantly being improved. For the latest in radon mitigation technology view the EPA web site at www.epa.gov/radon/pubs/mitstds.html (U.S. Army Corps of Engineers, 1998).

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