FLUCTUATION OF WATER LEVELS

The amount of water stored in the ground-water reservoirs is indicated by water levels in wells and may change for several reasons. Usually the fluctuation in water level is caused by changes in nearby pumping and in local precipitation. In some instances the cause of the fluctuation may not be immediately apparent and can be attributed to a combination of factors. Minor fluctuations of water levels may be caused by changes in barometric pressure or in other loads applied to the aquifer, or by earthquakes and earth tides. Such minor fluctuations do not indicate changes in storage.

Many of the shallow wells in the Purchase show a rise in water level soon after heavy local rains. The hydrograph of one well near New Providence, Calloway County (fig. 10), shows two periods when the water level rose about 1½ feet within a few days after heavy rains.

Pumping from a well will produce a cone of depression in the water table or in the analogous piezometric (pressure-head-indicating) surface of an artesian aquifer, which is observed in nearby wells as a lowering of water level. The water level in an observation well at Bardwell, Carlisle County is lowered about 5 feet when the municipal supply well 52 feet away is pumped at a rate of 178 gpm (fig. 11). The area in which water levels are lowered as a result of pumping for a given length of time is much greater under artesian conditions than under water-table conditions.

The effect of river stage on the water level in an aquifer is shown in the hydrograph of an observation well at the Ashland Oil and Refining Co. near Reidland in McCracken County. The water level in this well fluctuates with the stage of the Tennessee River, 500 feet away. The rise is attributed to loading of the artesian aquifer by increase in river stage. (See fig. 12.)

Changes in atmospheric pressure cause water-level fluctuations in artesian wells. Figure 13 shows the water-level fluctuations in a well near Lone Oak produced by changes in atmospheric pressure. The barometric efficiency of this well is approximately 73 percent—that is, if the atmospheric pressure rises by 0.88 inch of mercury (equivalent to 1.00 foot of water), the water level in the well declines 0.73 foot.

GENERAL GROUND-WATER CONDITIONS

The Jackson Purchase is the most favorable region in Kentucky for the development of ground-water supplies. Large supplies of water for public and industrial use can be obtained at many places, and domestic supplies may be obtained at almost any place. There are few localities without at least one good aquifer within 500 feet of the surface; in some areas there are two or more aquifers at different depths. In only one area, central McCracken County, is difficult to develop a ground-water supply. Here it may be possible to obtain water from Paleozoic bedrock at a depth greater than 500 feet.

Water is pumped from bedrock of Paleozoic age, the Tuscaloosa and Ripley formations of Cretaceous age, sands of Eocene age, gravel of Pliocene(?) age, and alluvium of Quaternary age.

The region lies at the north end of a southward-plunging rock trough which has been filled with layers of clay, sand, and gravel. A layer may consist of water-yielding sand (that it, may be an aquifer) in one place and may consist of non-water-yielding silt and clay in another. In some localities, two or more aquifers may lie one beneath the other, separated by clay beds. In general, a bed of sand that overlies a clay bed will contain a zone of saturation in its lower part and will furnish at least enough water for a domestic supply. A sand bed underlying clay also is generally saturated and will yield water, although the supply may not be permanent unless the sand bed extends to an outcrop where the water can be replenished. If the recharge area of an aquifer is at a higher altitude than a discharging well and the water-bearing bed is overlain by a relatively impermeable bed, the water may be under artesian pressure, though it will not necessarily rise high enough to overflow at the land surface.

The availability map (fig. 14) shows where ground water may be found in the Jackson Purchase region. In addition to general conditions this map shows, insofar as possible, the range in ground-water conditions resulting from facies changes within formations and from superposition of aquifers.

A columnar section listing the water-bearing characteristics of the different rock units is given in figure 15.

Along the eastern margin of the Jackson Purchase, limestone and chert of Paleozoic age crop out. Although these bedrock formations do not yield as much water as the unconsolidated formations to the west, they will yield fresh water in quantities sufficient for domestic and small commercial supplies. Water mineralized with brine and hydrogen sulfide is relatively uncommon in the Paleozoic bedrock in the Jackson Purchase, although it is present at depth in the bedrock in many other parts of Kentucky. An oil test hole in Ballard County is reported to have found fresh water in Ordivician limestone at a depth of 3,000 feet. Other oil test holes have found fresh water at shallower depths in the Paleozoic rocks elsewhere in the Purchase. It is likely that ground-water circulation extends to great depths in the consolidated rocks beneath the Purchase, at least for some distance west of the outcrops.

Water from wells and springs in the Jackson Purchase is suitable for domestic and most industrial uses; iron which may be present in objectionable concentrations is removed from most public and industrial water supplies. A few wells in the alluvium have a hardness (as $CaCO_3$) in excess of 400 ppm (parts per million), but water from the other aquifers is comparatively soft. Descriptions of the quality of water in each aquifer are given under the heading "Occurrence of ground water in geologic units."

QUALITY OF GROUND WATER

The general chemical character of water from aquifers in the Jackson Purchase is shown in table 1. Median rather than mean values of the amounts of dissolved constituents are shown, to minimize the effect of samples having unusual concentrations of certain constituents.

The principal ionic constituents in most natural waters are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and nitrate. Fluoride also occurs in ground water in small quantities. The metallic (basic) ions—calcium, magnesium, sodium, and potassium—are called cations. The acidic ions—bicarbonate, carbonate, sulfate, chloride, nitrate, and fluoride—are called anions.

The cations and anions will combine to form chemical compounds such as sodium chloride; conversely, salts, bases, and acids will dissociate in solution into their component ions. This combination or dissocation does not take place unit for unit by weight; for example, 22.991 ppm of sodium combines exactly with 35.457 ppm of chloride. In order to show how the anions and cations combine, the quantities can be expressed in chemical combining weights, or equivalents per million. Parts per million are converted to equivalents per million by dividing the parts per million by the combining or equivalent weight of the ion. Thus, a unit equivalent of the cation sodium combines exactly with a unit equivalent of the anion chloride to form the compound sodium chloride.

The hydrogen-ion concentrations, expressed as the pH (log of the reciprocal of the hydrogen-ion concentration, in moles per liter), is useful in indicating the corrosive tendencies of water. The pH scale ranges from 0 to 14; at a pH of 7, the midpoint of the scale, there are equal numbers of hydrogen and hydroxyl ions, and the water is said to be neutral. Values of pH smaller than 7 denote more hydrogen than hydroxyl ions, and the water is said to be acid; values of pH greater than 7 denote more hydroxyl than hydrogen ions, and the water is said to be alkaline. Acid solutions, generally, are more corrosive to metals than alkaline solutions.

The specific conductance of water is a measure of the ability of the water to conduct an electric current. The conductivity of water is related to the kind and amount of ionized substances in the water and is, therefore, a convenient means of indicating changes in concentrations of dissolved solids.

The dissolved-solids content represents the quantity of substances in solution, though the values reported may include some organic matter and water of crystallization. The U.S. Public Health Service recommends that the dissolved solids in a potable water supply preferably should not exceed 500 ppm, but 1,000 ppm is permitted if water of better quality is not available.

Hard water is usually recognized by the large amount of soap required to produce lather and by the deposit of insoluble salts formed when the water is heated. Hardness is due chiefly to the salts of calcium and magnesium, although aluminum, iron, manganese, and certain other metallic ions and free acid can contribute to the hardness. The hardness caused by calcium and magnesium equivalent to the bicarbonate and carbonate in a water is called carbonate hardness. The hardness caused by other compounds of calcium and magnesium is called noncarbonate hardness. The Geological Survey considers water having a hardness in the range from 0 to 60 ppm to be soft; that between 60 and 120 ppm, moderately hard; that between 120 and 200 ppm, hard; and that above 200 ppm, very hard.

The source and significance of the more common dissolved constituents in ground water are given in table 2.

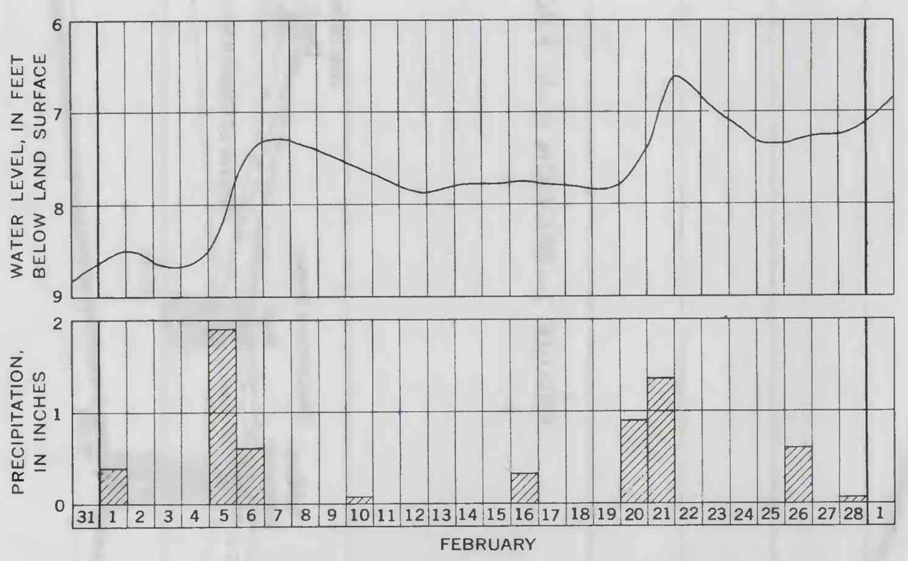

FIGURE 10—HYDROGRAPH OF A WELL 16 FEET DEEP NEAR NEW PROVIDENCE, AND PRECIPITATION AT MURRAY, CALLOWAY COUNTY, KENTUCKY

Table 1.—Median values of dissolved constituents in water from aquifers in the Jackson Purchase region, Kentucky

Aquifer and type of supply	Dissolved constituents (epm)					
	Magnesium and calcium	Sodium and potassium	Bicarbonate	Sulfate	Chloride	Nitrate
Paleozoic bedrock:						
Drilled wells	2.71	0.22	2.73	0.17	0.09	.01
Springs	.35	.22	.42	.03	.09	.01
Tuscaloosa formation:						
Drilled wells	.82	.18	.72	.20	.08	.00
Ripley formation:						
Drilled wells	1.31	.36	1.19	.28	.10	.00
Dug wells	1.30	.51	1.34	.17	.35	.03
Eocene series:						
Drilled wells	.64	.41	.81	.07	.15	.03
Dug wells	1.50	1.09	.89	.18	1.36	0.44
Gravel of Pliocene(?) age:						
Drilled wells	2.40	.60	2.33	.05	.13	.15
Dug wells	1.75	1.28	.80	.08	.64	.30
Springs	.30	.31	.27	.12	.22	.06
Quaternary alluvium:						
Drilled wells	2.43	.43	1.84	.17	.49	.06
Dug wells	1.59	.84	1.37	.56	.39	.30

Table 2.—Chemical constituents commonly found in ground water

Constituent	Source	Significance
Silica (SiO_2)	Siliceous minerals present in nearly all rocks.	Forms hard scale in pipes and boilers. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	The common iron-bearing minerals present in most rocks.	Oxidizes to a reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown and is objectionable for food processing, beverages. Larger quantities impart taste and favor the growth of iron bacteria.
Manganese (Mn)	Manganese-bearing minerals.	Rarer than iron; in general has some objectionable features; brown to black stain.
Calcium (Ca) and magnesium (Mg).	Minerals that form limestone and dolomite and occur in some amount in almost all rocks. Gypsum also a common source of calcium.	Cause most of the hardness and scale-forming properties of water; soap consuming.
Sodium (Na) and potassium (K).	Feldspars and other common minerals; ancient brines, sea water; industrial brines and sewage.	In large amounts give salty taste; objectionable for specialized industrial water uses.
Bicarbonate (HCO_3) and carbonate (CO_3).	Action of carbon dioxide in water on carbonate minerals.	In combination with calcium and magnesium form carbonate hardness, which decomposes in boiling water with attendant formation of scale and release of corrosive carbon dioxide gas.
Sulfate (SO_4)	Gypsum, iron sulfides, and other, rarer minerals; common in waters from coal-mining operations and many industrial wastes.	Sulfates of calcium and magnesium form hard scale.
Chloride (Cl)	Found in small to large amounts in all soils and rocks, natural and artificial brines, sea water, sewage.	In large enough amounts gives salty taste; objectionable for various specialized industrial uses of water.
Fluoride (F)	Various minerals of widespread occurrence, in minute amounts.	In water consumed by children, more than about 1.5 ppm may cause mottling of the enamel of teeth; about 1.0 ppm tends to reduce decay of teeth.
Nitrate (NO_3)	Decayed organic matter, sewage, nitrate fertilizers, nitrates in soil.	Values higher than the local average may suggest pollution. There is evidence that more than about 45 ppm NO_3 may cause methemoglobinemia ("blue baby") of infants, sometimes fatal; waters of high nitrate content should not be used for baby feeding.[2]

California State Water Pollution Control Board (1952).

[2]Maxcy (1950).

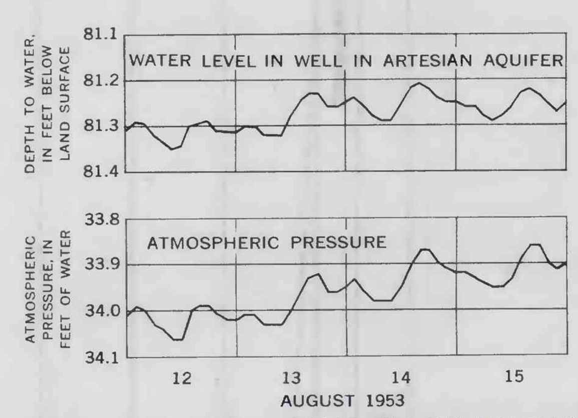

FIGURE 13—RELATIONSHIP OF WATER LEVELS AND ATMOSPHERIC PRESSURE

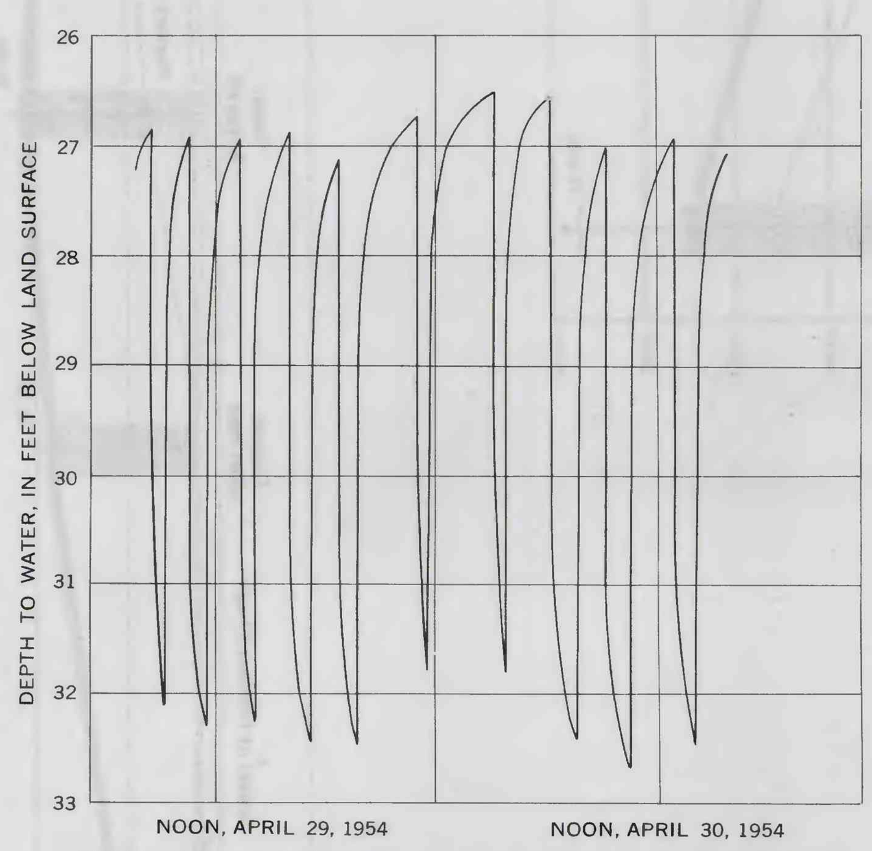

FIGURE 11—HYDROGRAPH OF A WELL 105 FEET DEEP, SHOWING FLUCTUATIONS CAUSED BY INTERMITTENTLY PUMPING 178 GPM FROM A WELL 52 FEET AWAY

FIGURE 15—GENERALIZED COLUMNAR SECTION AND WATER-BEARING CHARACTER OF THE ROCKS IN THE JACKSON PURCHASE REGION, KENTUCKY

SYSTEM	SERIES	GROUP	FORMATION OR UNIT	THICKNESS IN FEET	LITHOLOGY	TOPOGRAPHY	HYDROLOGY
QUATERNARY	Pleistocene and Recent		Alluvium	0–150	Sand and gravel in major stream valleys; silt, clay, and some sand and gravel in tributary valleys.	Flood plains and valley bottoms. Valley-train deposits beneath terraces along Ohio and Mississippi Rivers.	Known to yield as much as 350 gpm in major valleys. Yields sufficient water in tributary valleys for domestic use. Water ranges in hardness from 12 to 664 ppm and in dissolved solids from 53 to 1220 ppm. Iron may be present in objectionable amounts.
QUATERNARY	Pleistocene		Loess	0–40	Silt, compact, consisting of sharp, angular particles of quartz and small amounts of feldspar, hornblende, garnet, and epidote. Unleached beds calcareous.	Mississippi River bluffs and uplands adjacent to Ohio and Mississippi Rivers.	Yields small amounts of water to a few wells.
TERTIARY	Pliocene(?)		Gravel and sand	0–50	Gravel, iron-stained, mainly chert but includes small amounts of quartzite. Pebbles subangular to rounded; average diameter ½–1 inch. Sand, medium to coarse, orange or brick-red, and some gravel; mostly chert and quartz with some feldspar, hornblende, kyanite, and zircon. In places cemented by iron oxide into a hard conglomeratic sandstone.	Uplands and eroded edges of uplands above 370 feet.	Yield small quantities of water suitable for household use. One spring had measured discharge of 47 gpm. Most wells yield less than 10 gpm. Water-bearing gravel usually overlies clay or indurated layers. Water ranges in hardness from 8 to 724 ppm and in dissolved solids from 43 to 782 ppm. Iron content is generally low.
TERTIARY	Eocene	Wilcox and Claiborne	Sand and clay	0–1000	Sand, fine to coarse, gray, white, brown, or yellow. Particles mostly rounded to subrounded quartz and some feldspar and mica. Layers indurated by iron oxide at contact of sand and clay or at contact of sands of different permeability. Clay, jointed, smooth and fine to gritty. Color ranges from white to brown to black; depending on amount of lignite and iron oxide present. Marcasite concretions common.	Uplands and high-level erosional surface over most of area. Extend beneath river terraces along Mississippi valley.	Sand yields enough water for domestic use near outcrop area of Porters Creek clay and in areas of perched water. Drilled wells penetrating main zone of saturation where beds are thick yield as much as 1700 gpm. Hardness of water ranges from 7 to 212 ppm, and dissolved solids from 28 to 431 ppm. Iron may be present in objectionable amounts.
TERTIARY	Paleocene	Midway	Porters Creek clay	0–369	Clay, light- to slate-gray, in laminae separated by thin layers of mica and very fine sand. Clay well jointed and breaks with conchoidal fracture, in places cut by sandstone "dikes." Lower part of clay glauconitic, contains meager fauna consisting of Foraminifera and Pelecypoda.	Crops out along Clarks River valley and in the adjacent uplands from Tennessee Stateline to Paducah. West of Paducah it is truncated and covered by river alluvium.	Probably will yield a little water from joints and from sandstone "dikes." Water is probably hard and high in iron. Formation is important as a confining layer.
CRETACEOUS	Upper Cretaceous		Ripley formation	0–400	Sand and clay, interbedded; thin zones indurated by iron oxide at contacts of sand and clay. Sand is white, buff, yellow, and red; clay ranges from white to dark gray. Formation consists mostly of silt and clay in some areas.	Uplands and dissected ridges between Kentucky Lake and Clarks River. West of Paducah, it is truncated and covered by river alluvium.	Yields sufficient water for domestic use near outcrop area of Paleozoic bedrock and in areas of perched water. Where formation is thick, drilled wells yield as much as 830 gpm. In areas where formation is mostly silt and clay, there may not be sufficient saturated sand to furnish even a domestic supply. Hardness of water ranges from 13 to 182 ppm, and dissolved solids from 62 to 275 ppm. Iron may be present in objectionable amounts.
CRETACEOUS	Upper Cretaceous		Tuscaloosa formation	0–50	Gravel, rounded, and chert, in matrix of angular chert, sand, and clay. Average diameter of pebbles 1½ inches.	Dissected ridges adjacent to Kentucky Lake.	Yields small amounts of water to domestic wells. Yields are low, owing to clayey matrix and poor sorting. Hardness of water from 2 wells sampled was 26 and 57 ppm, and dissolved solids, 50 and 76 ppm.
DEVONIAN AND MISSISSIPPIAN			Limestone and chert		Limestone, chert, and shale. Chert beds commonly fractured to a depth of several hundred feet. Thin beds of clay and tripolite interbedded with chert in some places.	Dissected ridges adjacent to Kentucky Lake. Valley of Tennessee River from Gilbertsville to Calvert City.	Usually yield sufficient water for domestic use; known to yield 120 gpm in some localities. Fresh water found at depths exceeding 1000 feet. Hardness of water ranges from 17 to 238 ppm, and dissolved solids from 39 to 273 ppm.

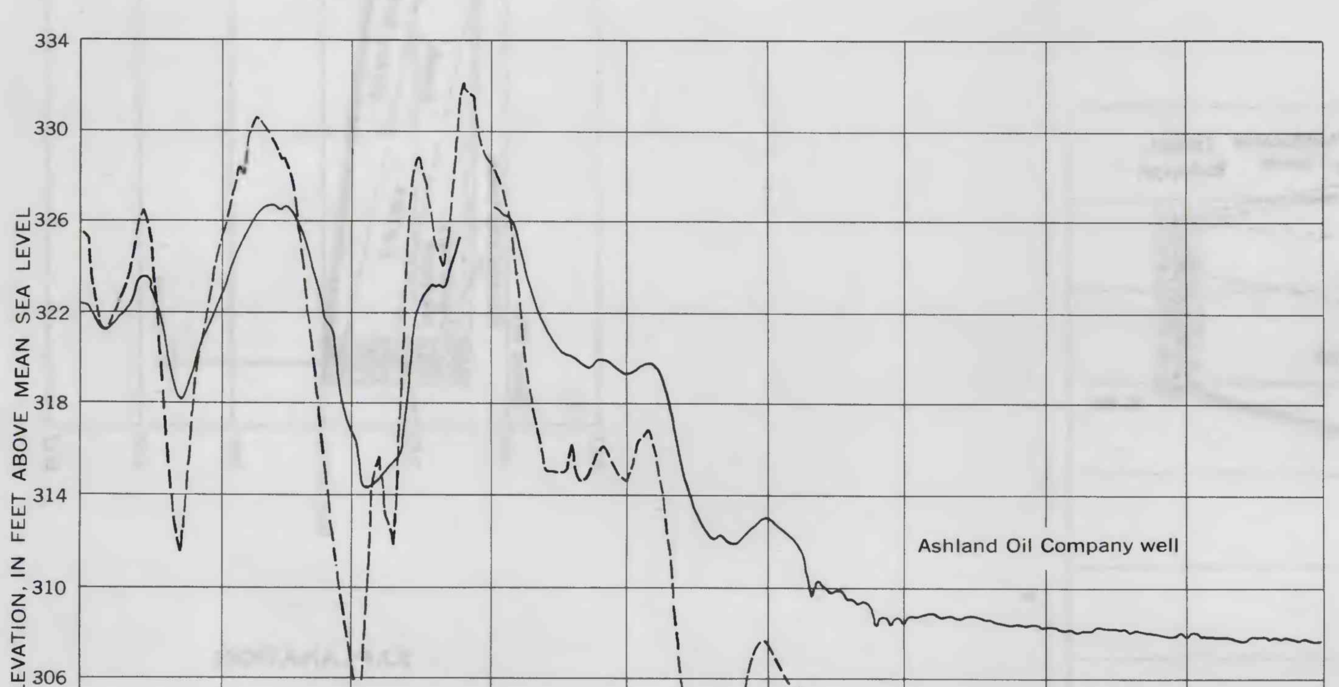

FIGURE 12—HYDROGRAPH OF A WELL 227 FEET DEEP IN THE RIPLEY FORMATION NEAR REIDLAND, MC CRACKEN COUNTY, KENTUCKY, AND STAGE OF THE TENNESSEE RIVER